Designing Good Practices for Recruitment, Admissions, and Program Structure of Engineering Outreach Programs to Increase Access for Marginalized and Non-Traditional Higher Education Students

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Designing good practices for recruitment, admissions and program structure of engineering outreach programs to increase access for marginalized and non-traditional higher education students (Evidence-based practice)

Abstract

Engineering outreach programs aimed at students in higher education play a key role in providing pathways for students to access studies and careers in engineering. Marginalized and non-traditional students may not have the resources to represent their skills, goals and fit in the parlance and format that best matches program requirements and expectations, particularly during recruitment and admissions. This lack of knowledge of this 'hidden curriculum' can result in barriers to accessing and participating in outreach programs, despite the programs being designed to serve and actively seeking these underserved student populations. This paper presents a literature review that identifies good practices for the equitable design and implementation of outreach programs in engineering higher education that help lower these barriers and increase access. The paper also thematically analyzes two case studies of outreach programs that create pathways into engineering in the United States, and that have been designed to address these barriers, to describe good practices for recruitment strategies, equitable admissions & selection processes, and program design. The two case studies consist of an online program designed for computer science and engineering students, and an in-person program designed for aerospace students at community colleges. Insights will be gained by qualitatively analyzing program materials and staff perspectives for the purpose of improving program quality. The paper uses the literature research and the insights gained from the case studies, to extract a set of practices that would be of interest to designers of similar engineering outreach programs that serve marginalized and non-traditional students in higher education.

Introduction

Engineering outreach programs for students play a crucial role in fostering inclusivity and providing pathways for marginalized individuals to pursue engineering by familiarizing students with engineering careers [1]. Increasing the participation rate of diverse and marginalized demographics in engineering continues to be a critical aspect of meeting the increasing shortfall of engineers in the United States, as seen in Figure 1. Effective partnerships between research universities and institutions with large populations of students from underrepresented backgrounds plays an important role in addressing this shortfall [2]. Increasing participation is a key part of maintaining the overall participation rate in engineering, and essential to fueling innovation in the United States [3], [4], [5], [6]. The shortfall is set to get worse, with predictions of a growing demand for engineering skills increasing by ~13% from 2023 to 2031 [7]. Despite the growth in the number of outreach programs focusing on increasing the participation of diverse students, marginalized and non-traditional students often still encounter barriers during the recruitment and admissions processes of such outreach programs [8].

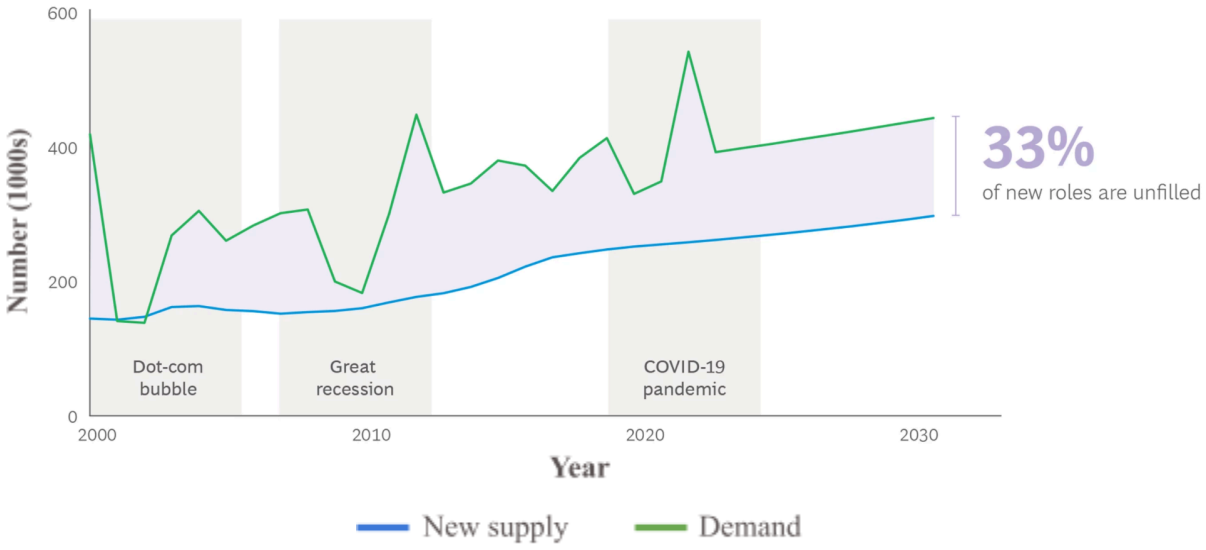

Figure 1: New engineering employment opportunities compared to new engineering talent, showing a talent gap of 33% of unfilled employment opportunities [adapted from 7]

Among many factors, students' lack of experience and access to resources impacts their ability to effectively communicate and represent their academic and wider potential to outreach programs, due to having less access to knowledge of how this information is expressed and utilized for program admissions. This disadvantages the very students the outreach programs are seeking to recruit, admit and support. This phenomenon is rooted in the concept of the 'hidden curriculum', which encompasses the implicit expectations and norms that may not be evident to students [9]. The "hidden curriculum" includes the approaches, values, or attitudes that are taught to students implicitly and inadvertently [10]. While these lessons are often not explicit or part of the educational goals for students, understanding and mastery of them is essential for successful progression through education [11].

The design and curriculum of the outreach program, both during and afterwards, also can present inequities for students with less access to a wide range of academic and logistical resources. For example, students with fewer resources may be disadvantaged by less ability to have transportation to a program location, less access to laptops and other technical equipment and software needed to successfully complete the program objectives, or less time available to continue working with mentors for further applications to higher education or employment opportunities. The program's application requirements may also present inequalities despite seeming pertinent, for example requiring an official transcript can create unintentional barriers for students due to the financial cost and logistical burden of ordering an official transcript, as financial limitations are a key barrier to students' academic plans, especially for first-generation students [12]. This range of academic and socioeconomic barriers can result in reducing the participation of underserved student populations in outreach programs, despite the programs being intentionally aimed to serve these populations.

Solutions can be found in alternative program design structure, and small changes can make large impacts in removing barriers so a diverse population of students have equitable access. For

example, removing the need for official transcripts and instead only requiring unofficial transcripts or a captured 'print screen' of students' grade information on their organization's registration software system, reducing financial barriers to less resourced students. By designing outreach programs to overcome these barriers, by building-in recruitment and admissions processes that address inequities in students' ability to represent their achievements and potential, and inequities in meeting the financial and logistical burdens of making an application, programs can help ensure underrepresented students have more equitable access to such programs. Ensuring that the pool of applicants is diverse results in a more diverse program cohort, supporting the pipeline of underrepresented populations in joining a career in engineering.

With our recommendations, we strive to promote inclusive practices to actively engage students, beyond utilizing such means to merely increase representation. Marginalized students bring a breadth and variety of knowledge and experiences that benefit the field, moving us past representation as a goal unto itself. It is important to note that we believe that access on its own, is not equivalent to inclusion. Therefore, our recommendations are not intended to exclusively increase numbers of marginalized students, but rather create truly inclusive pathways for students to comfortably apply and join our outreach efforts. Students' self-developed identity has a strong impact on their retention within engineering studies and careers [13], so it is vital for outreach programs to define this population for diverse students, in order to be able to meet their needs. While the definition of marginalized and non-traditional students can be complex to determine, for the purposes of this paper, *marginalized* is defined as students historically and currently marginalized in engineering, which may have intersectionality with different identities that impact educational outcomes (such as race, cultural and socioeconomic, citizenship, to name a few among many other identities), creating a unique consequence of all the interlocking oppressions faced as marginalized students [14]. This also includes marginalized students, including First-generation and Low Income (FLI), and non-traditional students who experience barriers in accessing engineering studies and careers despite not fitting neat definitions of marginalized, such as mature students who have returned to education after being in the workforce. Within this paper, the terms marginalized and underserved are used interchangeably, and similarly, program design and program structure are used interchangeably.

The outreach programs used as case studies in this paper were designed to recruit students into and to create pathways into engineering studies and careers, and not specifically for increasing college admissions for marginalized students. The good practices explored in this paper are specifically practices for short-term outreach programs, particularly those used to connect to and recruit marginalized students, and do not have to meet the precision and legal rigor of college admissions. Recent changes in 2023 to U.S. federal legislation effectively eliminated affirmative action for college admissions [15]; these changes will also impact how outreach programs communicate with, recruit, and make decisions on admitting program participants. Affirmative action is the process of positively discriminating students from under-represented populations in college admissions, on the basis of race or ethnicity (and other protected characteristics, including disability, sex, sexual orientation and gender identity) [15], in order to address historical inequalities in college admissions and retention. This paper is situated in the context prior to this decision, where applicants' gender, race, etc were asked for (but were optional for students to disclose). The program staff in both case studies had all received training to address

intrinsic bias, including methods during application decisions such as using partially de-identified application materials used in admissions decisions.

Positionality

This work is presented from the positionality of the researchers at Stanford University, examining outreach programs situated in the United States and in Lebanon, from the author perspectives of the program designers and staff. The authors have a focus on supporting access and equity in engineering, and approach this from a practical perspective of finding practices that can be integrated into current educational outreach efforts. As a result, we briefly reflect on our personal experiences in relation to the topics we address in this work in this brief positionality statement [16]. Aya Mouallem is an engineering PhD candidate in the United States, originally from Beirut, Lebanon. She was one of only two female students in her introductory engineering lab during her undergraduate studies. This drove her to pursue engineering and found and support multiple outreach initiatives across Lebanon, the Middle East, Eastern Europe, and India to encourage young women and marginalized students to pursue STEM fields at the college and beyond. Dr. Sonia Travaglini is an engineering educational specialist, with international experience working with marginalized students in higher education, and a passion for increasing access to engineering. Recently awarded the Stanford University James and Anna Marie Spilker Award for Diversity Equity and Inclusion, in recognition for exceptional work done promoting greater diversity, equity, inclusion, Dr. Travaglini founded the Aeronautics and Astronautics Community Research Experience (AACRE) program at Stanford University to provide marginalized students pathways to access engineering studies and careers. Sheri Sheppard is a recently retired faculty member in Mechanical Engineering at Stanford. Much of her life's work has focused on increasing access to engineering through active teaching methods, modern course topics, outreach and bridge programs, and research on engineering education and career pathways. She fervently believes that engineering is critical to building a healthier future for everyone---and diverse people and ideas are key in this enterprise.

Methods

This paper aims to explore effective practices for the equitable design and implementation of outreach programs in engineering higher education, which help overcome the barriers in recruitment, equitable admissions, and selection processes. This paper aims to answer the question for designers of similar programs:

How do you design recruitment, admission, and content for engineering outreach programs to increase access of marginalized and non-traditional students to such programs?

Answering this question will be achieved through a literature review and analyzing two case studies using thematic analysis, finding common themes of practices that are identified as reducing barriers or increasing access for marginalized and non-traditional students to such programs.

The literature review delves into existing research on pre-college and early-college engineering outreach programs, focusing on the challenges faced by marginalized and non-traditional students in accessing and participating in such initiatives. The review highlights key factors

contributing to barriers and proposes effective strategies for mitigating these challenges. The case study analysis presents two case studies of successful engineering outreach programs, situated in two different geographic locations and cultural backgrounds; the AACRE program in the United States, and the LebNet Tech Fellows program in Lebanon. Exploring marginalized students in two different cultural and academic contexts helps identify practices that lower barriers for marginalized students that can be transferred from programs in different contexts. Both the AACRE program for community college students, and the LebNet Tech Fellows program for pre-college and Freshman-Sophomore students, were designed from the 'ground-up' specifically to serve marginalized and nontraditional students, and both help create pathways for students to succeed engineering studies and careers.

The case study of AACRE, founded during the 2020 academic year at Stanford University, focuses on an in-person program designed for supporting aerospace students at community colleges with pathways to careers in engineering. The LebNet Tech Fellows program, founded in 2023, works with a range of Lebanese universities and features an online program tailored for computer science and engineering pre-college through to junior students. Both programs have similar goals of supporting underrepresented adult students during their pre-college or early-stages of engineering studies; specifically 2-year community colleges in Stanford University and Freshman/Sophomore/Junior of 4-year college studies joining the LebNet Tech Fellows, respectively. Both programs were designed from the outset to address inequities for marginalized students applying and being admitted to the programs.

Examining the *recruitment strategies* employed by the case studies will shed light on effective approaches for reaching and engaging underserved student populations. The *admissions and selection processes* of outreach programs are critical junctures where barriers can either be reinforced or dismantled. This section includes analysis of the case studies to identify practices that ensure fairness and equity in the evaluation of applicants. The methodology for the examination of these case studies is based on thematic analysis [17], drawing out common themes from analyzing the programs' materials, program structures, admissions processes etc, which are identified as being designed to support marginalized and non-traditional students in accessing the outreach programs. Thematic analysis of program materials, including brochures, websites, and application documents, will provide insights into the intentional design choices aimed at lowering barriers for marginalized students.

By thematically analyzing program materials and incorporating staff perspectives, the paper will identify features that contribute to successful program designs. By thematically examining these case studies, this paper will identify good practices in recruitment strategies, equitable admissions and selection processes, and overall program design, which will be of interest to designers of similar engineering outreach programs for marginalized and non-traditional students in higher education. Synthesizing findings from the literature review and case studies, a set of general principles and guidelines for program developers to ensure inclusivity and accessibility will be developed. These emergent themes will be used to express specific good practice recommendations, highlighted in **bold** throughout each section of the paper, and summarized into an infographic in Appendix 1, and checklist in Appendix 2. Strategies for addressing the hidden curriculum when connecting and participating in outreach programs will be explored, with an emphasis on understanding it and the implications for program design.

Existing equitable design practices in higher education engineering outreach programs

National organizations promote increasing participation of marginalized groups in engineering through numerous outreach initiatives, resulting in a rich landscape of academic reporting. The National Academy of Engineering's 2002 survey found over $400 million is spent annually on such activities [6]. This study focuses on post-K-12 education outreach programs, excluding K-12 initiatives to narrow the scope. It aims to identify good practices tailored to students navigating pre-college and early collegiate pathways into engineering, limiting the review to pre-college and first-year outreach programs. While research often examines the impact of K-12 outreach on STEM degree pursuit [18], [19], [20] and higher education retention in engineering [21], [22], [23], this work specifically targets pre-college and early collegiate pathways.

Search terms used in Google Scholar, an online search engine for scholarly literature across an array of publishing formats and disciplines, included the search terms shown in Appendix 1, and yielded several hundred results, in varied topics. Discussion of good program design practices was situated across many domains, including Diversity, Equity and Inclusion (DEI), retention, identity, experience, etc. Results were filtered based on abstract reading to determine the topic and information fit with the search topics. The scope of this research required selection of a set of papers which addressed the research question narrowly, resulting in a small pool of papers that addressed admissions and recruitment of marginalized students in pre-college but post-K-12 programs, specifically in engineering education and tailored to engineering discipline. Results that focused on K-12 education despite the exclusionary search terms were disqualified.

Of the total papers returned during the search phase, the papers by Ashley et al. [24] and Aulck and West [27] were selected for further analysis, due to providing meta-analysis of many individual programs, being situated in engineering disciplines, and containing rich information on the outreach program design. Both of the papers selected for analysis had discussion of the program design, either as a central theme or as part of the discussion of design elements that were successful, for example discussing the inclusion of mentors in creating successful program outcomes. Ashley et al. [24] completed a meta-analysis of 46 publications on 30 ‘bridge’ programs, which support students transitioning into 4-year engineering degree programs. ‘Bridge’ programs have strong similarities to outreach programs, as they connect potential engineering students, especially marginalized populations who may need more support, to four-year educational institutions. Ashley et al recommended the use of theoretical frameworks that are used in research of students attrition from engineering studies, as a guide to selecting the program goals and the activities, becoming design elements that address the main causes of students’ departure from engineering programs described in the frameworks. This design approach can be applied to the program’s application materials design, to help connect students’ skills and interests to the program’s available outreach mentors and activities.

Program design approaches

Ashley et al. recommended the **use of ‘backward design’ as a model to develop the outreach program**. ‘Backward design’ is a design methodology where the desired outcomes lead the process, first outlining the desired outcomes, expressing these as goals, and then designing the

activities and experiences to meet these goals [25]. This design approach helps ensure the program activities, and evaluation of the outcomes, match the goals of the program - which should also be clearly identified ahead of designing the program activities and structure.

A similar design approach is **student-centered program design, where the needs and desired outcomes of the student become the core values around which the program is designed**. This ensures the program design is fitted to, and evolves with, the needs of marginalized students, which may be very different to other student populations. Student-centered program design frameworks can amplify students' rewarding experiences, minimize their unproductive struggles, and preserve healthy challenges that effectively contribute to the students' learning process [26]. For example, pre-collegiate and first-year students have less experience in articulating which engineering discipline they are interested in, or which sub-discipline of an engineering field they wish to pursue. Students may indicate they are interested in 'aerospace engineering' but lack the experience to determine what aspect of aerospace they wish to explore. **Using a student-centered design approach to address this, the program application is designed with questions to elicit students' curiosities, interests, and hobbies with connections to engineering, to best match students to an engineering domain or project topic** - and thus more successful outcomes and student satisfaction with the program.

Goal setting

Aulck and West [27] analyzed 70,000 student records to consider prior attendance at a community college on performance, persistence, and academic migration of students enrolling in four-year degrees. They suggested that students' degree of uncertainty about their educational pursuits impacted migration within degree programs, with transfer students (from community college) having more defined educational clarity and trajectories for post-transfer, resulting in being less likely to migrate between degree programs. This finding can help inform the design of outreach program goals, by **setting a goal of the program to increase students' level of knowledge and clarity around the engineering domain and career trajectory.** This would result in a better student-field fit, thereby increasing the likelihood of continued participation in the program. In addition, it could potentially decrease their likelihood of future attrition from or migration within a four-year degree program. It can also help inform program activity design - for example including peer-connections and panel events to connect outreach program participants with current students and researchers from various engineering domains allied to the outreach participants' selected field of study. This provided the outreach program participants with a richer understanding of what engineering domains and degree programs they wish to aim for as they progress in their pathways into higher education.

Effective communications

Ashley et al [24] highlighted the difficulty of connecting to eligible students for recruitment and complications of communication to them, as by definition, the students to be recruited are not yet connected to the four-year institution providing the outreach program [24]. Focusing recruitment efforts on students from community colleges, which have a high proportion of marginalized students, helps ensure the program is made available to them. The **program recruitment materials should be designed to address common barriers these students face, clearly**

indicating the financial, academic and logistical support available during the program. Personalized communication can also increase the likelihood of low-income students choosing to attend college [28], so **a single individual should be the program's designated contact person, so that applicants feel more comfortable asking questions or asking for support in the application process**.

Identifying and reducing barriers

Research relating to barriers to marginalized students' enrollment can also be applied to the design of the program logistics, to ensure similar barriers are removed for participating in outreach programs. For example, **removing financial costs in applying (some of which may be less obvious than application fees, such as transportation costs to attend interviews), can increase students' likelihood to apply** [29] especially for under-represented populations [30]. Solutions built into the program design to address these barriers can be simple to implement, such as ensuring candidate interviews are completed online using a web-conference platform such as Zoom as opposed to in-person interviews, removing the time and financial barriers marginalized students are disadvantaged by.

The literature review highlighted the approach of using 'backward design' where the desired outcomes lead and inform the process as a good practice in the development of outreach programs. A similar design approach is student-centered program design, where the needs and desired outcomes of the student become the core values around which the program is designed. Applying this design method to program applications, including using questions mindful of the barriers students face and which are designed to elicit students' connections and familiarity with engineering, helps best match students to the outreach programs. These approaches help ensure the program activities and evaluation of the outcomes match the goals of the program, and help ensure more successful program outcomes and student satisfaction with the program. The two following case studies of outreach programs further explore good practices around recruitment, admissions and program structure design that help lower barriers for marginalized students.

Case 1: Aeronautics and Astronautics Community Research Experience (AACRE)

Inaugurated in 2021, Stanford University's AACRE outreach program aims to assist marginalized and non-traditional community college students in accessing higher education. Originating from student feedback during departmental meetings, the program addresses the need for diversification in admissions and engineering career pipelines. Developed by the Aeronautics and Astronautics department, it employs student-centered design principles, addressing barriers like the cost of necessary equipment by providing loaner laptops. The program offers a 10-week summer research opportunity, enhancing participants' skills and understanding of engineering and research methodologies. Implicitly, it aims to boost students' confidence and sense of belonging, factors linked to persistence in engineering studies [31]. With a capacity for two students annually, it ensures robust funding and individualized support. All six past participants have successfully transferred to four-year engineering degree programs.

Communications and application design

Utilize direct recruiting at community colleges serving marginalized populations: Direct advertising to students enrolled in STEM classes and educational support groups at local community colleges, was found to strongly increase the proportion of applicants from marginalized communities and diverse backgrounds. **Create holistic application design and processes**: Applicants' GPA is not requested or considered in the application, to ensure that students' potential is the criterion the selection committee uses to assess students, as academic achievement is not a good stand-alone indication of student persistence in engineering [32]. An example from the Stanford University outreach program is the application question "*Describe something you made or created that you were proud of, from a hobby or as part of a club/group - for example an item, a design, a project, or even an idea you've been working on. Tell us about what you enjoy doing!*", to explore applicants' self-motivation and ability to apply their technical knowledge to practical work (key skills for successfully completing an aerospace research project). Application materials should also **explicitly define terms that applicants may not have come across before, to remove a barrier of a 'hidden curriculum' by explaining speciality vocabulary**. For example, the application gives examples of what 'low-income' and 'first-generation' means, so students can make informed decisions on if their identity matches these characteristics. The **questions in the application provide suggested guidelines for the length of responses, and describe the purpose and use of the information being sought**, such as describing how the requested writing example will be provided to the selection committee to understand their ability to synthesize and effectively communicate information. The application is also designed to give a broad latitude of what written material the applicant feels best represents their interest and skills, only requiring the artifact to be nonfiction, providing applicants with more diverse options than traditional requirements such as only accepting essays. For example, several applicants submitted Powerpoint presentations which showed their technical achievements in a class project, and their ability to communicate technical ideas. Finally, the **application is made easy to access, with QR codes linking to the application form provided on all program advertisements**, and ensuring the application form is stable and easy to use on a mobile phone platform, helping reduce the barriers of students having the time and resources to complete the application. Unsuccessful applicants are offered free online workshops for resume writing and connections to other opportunities, and communications highly encourage applicants to re-apply for future programs.

Admissions process design

To widen access the grade or GPA level is not used as a comparative criterion to select between applicants, instead considering students prior completion of STEM classes. Students in the early stages of their engineering studies may not have completed many STEM classes and this should not be a barrier to their participation in the program, which is designed to provide a research project experience that meets the students at their specific and unique skill level. The selection committee is purposefully composed of a range of Stanford University community members, including students, faculty, and educational support staff. **Creating a selection committee with a broad membership and diverse perspectives helps reduce intrinsic bias**. Selection committee members are provided with a rubric to rank applicants, **using applicant evaluation categories that help the selection committee determine the applicants' level of interest, passion and motivations, as opposed to purely academic achievements**, which help select participants likely to persist with the program. This also helps solve the

‘hidden curriculum’ problem of evaluating applicants’ potential as a scholar in engineering, despite the applicants not having the prior experience or knowledge of exactly what engineering topic they wish to research, or exactly what domain of engineering they are interested in. For example, an applicant expressing their passion for prototyping and flying drone aircraft shows their high potential to complete technical activities within the program and build various engineering skills.

Program structure design

Offer flexible employment hours to empower students from diverse backgrounds: Accommodating flexible hours enables participants to fit the program into the demands of their lives, such as concurrent community college classes or personal responsibilities they may have such as caregiving duties. Program materials and application questions are designed to clearly describe the flexible nature of the program, helping reduce perceived barriers that discourage marginalized and non-traditional students from applying and participating. **Provide robust funding to focus on studies while allowing participants to maintain external responsibilities**. Participants from community colleges often have to work part or full-time to support their studies and to meet financial obligations they may have to their families or other responsibilities. Providing funding as earnings paid directly to the participant, rather than in benefits such as providing housing, helps replace other income the participant usually relies on during the program and ensures participants are empowered during the program to focus on their studies.

Create individualized research project design based on participants’ unique skillset and academic trajectory: Participants are paired with a faculty mentor leading one of the research laboratories in Aeronautics and Astronautics department, who works with the participants to develop and complete a research project under the guidance and mentorship of the faculty mentor within the 10 week program. This highly individualized project design approach ensures that the project objectives meet the participants at their unique set of skills and academic level. For example, participants who indicate strong mathematical skills and an interest in applying them using software were matched with faculty members researching simulations. Whereas other participants who showed high ability at fabrication work in creating physical objects, were matched with faculty members who complete applied research with empirical experimentation, such as prototyping deployable spacecraft structures being developed as part of a NASA research project. **Center program activities on the development of academic and professional skills:** Projects have involved engineering design, computational analysis, modeling, and/or simulation, but all feature common elements of critical skills students will use in higher education degree programs, such as technical report writing and conducting a literature review. Students also participate and share in regular research meetings with the faculty members' research students, and present their research results at a final research symposium to the Stanford community. **Develop tangible artifacts to strengthen participants’ access to pathways into higher education**: The research project activities are designed to develop the skills students need to advance in their studies and careers in engineering, providing the participants with a ‘resume building boost’ in their pathway into higher education. Participants are helped to overcome the ‘hidden curriculum’ issue of how to express their interests and describe their achievements, in the often implicit format and parlance customarily used in higher education applications.

Provide support to navigate academic and professional landscape: Students participate in mentoring meetings with program staff and students of Stanford University, professional development workshops, and social activities, to develop familiarity with the higher education ecosystem and various academic, educational and technical careers. **Provide long-term professional development support**: Participants are assigned an individual program staff member to provide post-program support for college applications, resume workshops, career resources, and support in seeking and securing opportunities throughout the educational journey of program participants, including as they enter the engineering workforce. **Provide connection to community to encourage students to explore engineering identity and belonging**: The program partners with other educational outreach programs at Stanford University to provide opportunities to network with wider academic communities (and social events to have fun!). Participants are encouraged to immerse themselves in the community, helping them develop belonging and and explore their emergent engineering identity. Past program participants are asked to provide perspectives of their program and research experiences, including successes and challenges, which (with the consent of participants) are published so that current program and future potential participants can get a sense of the program and the overall experience. Connecting previous participants to current participants as peer mentors, with support and oversight by the program's mentor, is beneficial to share useful information and help students build wider connections to academia and/or industry.

Use iterative program design informed by multiple perspectives on program evaluation: Program participants should complete a pre-and-post survey instrument that elicits qualitative and quantitative measures of their academic, technical, and professional skills, program experiences both positive and in need of improvement, and asked for their ideas of how to develop the program. Faculty mentors and program staff are also invited to share their experiences, and ideas to improve both their and the participants' experience. These are analyzed by program staff each year, and used to iterate the design of all aspects of the program.

Case 2: LebNet Tech Fellows program

Since its launch in 2023, the LebNet Tech Fellows program has expanded to serve 99 fellows from more than six universities and colleges across Lebanon. The non-profit brings together more than 3,000 Lebanese professionals in technology in North America, to act as mentors for students in Lebanon to support and nurture the next generation of Lebanese technologists. The program serves marginalized and non-traditional students, at an education stage of pre-college, as well as Freshman, Junior and Sophomore students enrolled in four-year engineering degrees. Applicants for the fellowship are generally pursuing engineering fields or tangential fields with heavy computational emphasis, such as statistics or bioinformatics. The program focuses on supplementing students who are transitioning into higher education with the soft skills, networking opportunities, shadowing experiences, and community bonds necessary to successfully launch a career in technology.

Communications, application and admissions process design

The LebNet Tech Fellows program is advertised by the communications team through the monthly LebNet Tech Fellows newsletter sent to thousands of community members, in addition

to marketing on the LebNet Tech Fellows official website (https://lebnet.us/TechFellows), and to career offices at universities. **Advertise programs in the communication channels marginalized and non-traditional students are connected to**: Short advertisements and links to the program application are shared on LinkedIn and social media platforms, as Lebanese undergraduate students typically use these to build networks and seek professional development opportunities. The application is designed to reduce barriers due to socio-economic, political, or intrinsic bias that often prevents marginalized students from accessing opportunities, through a holistic approach to question design and selection processes. **Accept unofficial university (or high school) transcripts, and do not charge an application fee or any costs to participate in the program**: Official transcripts can impose a financial burden on the students, to prevent the exclusion of applicants based on their financial capabilities, many of whom are experiencing poverty and other issues due to the impact of national conflicts. **Provide broad options to demonstrate sufficient English language proficiency** to ensure that students applying with weaker language backgrounds were not excluded if they meet the rest of the program requirements. **Application questions designed to help applicants demonstrate their genuine passion for pursuing a career in technology** helps students explain how their engineering studies will help them meet the program expectations and take advantage of the program. Using **questions seeking brief but introspectively reflective answers, utilizing a non-formal tone in posing brief prompts for applicants to reflect on**, **with simple examples** encourages participants of any background and helps avoid alienating participants with less relevant experience or limited financial resources. Questions also **avoid jargon, technical terminology, and unnecessarily complicated vocabulary**: For the phrase "first-generation, low income" (FLI) is not terminology used worldwide, therefore describing such terminology with simpler language in all program communications, including email responses and in marketing materials helps applicants communicate their unique needs. **Application questions inviting applicants to reflect on setbacks and challenges that they've faced in life** help reveal and decrease the impact of applicants' First-generation, Low-Income status, imposter syndrome, health challenges, or any other barriers that impact students' access to outreach programs.

In order to reduce barriers for students with good potential who are struggling with the transition to university resulting in lower grades, **grade scores are not used for admissions decisions, instead focusing on completion of courses that indicate interest in engineering.** To reduce the impact of intrinsic bias, **the admissions decision process made use of a team of program members, reviewing partial sets of applications in parallel first and cross-reviewing** decisions and comments. **Unsuccessful program applicants were encouraged to apply again for the next cohort and to make use of other offerings by LebNet Tech Fellows, including mentorship programs, communications about other internship opportunities, and year-round engineering outreach-related events.** This ensures the pool of potential applicants is preserved for future program years, and helps students have support to develop pathways, even if they are not selected to participate in the program.

Program structure design

All activities are offered online to eliminate transport costs for participants, and to accommodate larger program cohorts. To enable the program to scale up and meet the needs of larger cohorts with diverse educational trajectories, the program offers four pathways, 'Undergraduate 101',

‘Pathways to Tech’, ‘Cracking Your Future’, and ‘Radical Paths’, tailored to the students’ career trajectory. For example, the ‘Undergraduate 101’ pathway features courses on seeking volunteer and research internships, and the ‘Radical Paths’ pathway features Ask-Me-Anything sessions with guest speakers who pursued non-traditional career paths in technology. All pathways also feature guest speakers providing insight and advice based on their experiences in their areas of expertise. **Participants are assigned to a mentor to support the creation of internship and academic application materials, and support to explore career interests**. The team also **incorporates ice breakers into program sessions, and social events to support community building**. After the program ends, fellows remain connected to the LebNet Tech Fellows community, with many fellows from the 2023 cohort returning to the program as volunteers in 2024 to support incoming fellows. Along with regular program improvement design reviews, program improvements are sought through **pre-program and post-program surveys to explore the influence of the program on the participants,** including their sense of belonging and confidence in pursuing opportunities in the field.

Discussion of emerging recommendations for good practices

This paper focused on emerging good practices by conducting a thematic analysis of a brief literature review, evaluating program materials and staff perspectives, and considering their viewpoints on successful program design through two case studies on outreach programs. The results are not generalizable at this smaller scope of research, but is designed to be a continual documentation of emergent good practices. Using ‘backwards’ design principles helps programs understand marginalized and non-traditional students’ unique needs, to design program structure that meet these needs, ultimately lowering barriers to participation. The two case studies of outreach programs, both designed to serve marginalized and non-traditional students, identified the value of direct recruiting, and of providing communications and adverts about the programs within the channels that marginalized populations widely use. The importance of the design of the application in lower barriers was highlighted, utilizing questions that dig into students’ motivations and passions, and giving examples of what information is being sought and how it will be used in admissions decisions. This helped address one of the ‘hidden curriculum’ conundrums–how to connect to the students most needing the support of these programs, who lack the experience and knowledge necessary to connect to such support. Important aspects of successfully supporting students were identified, including financial support, mentorship and the role it plays within student persistence in engineering, development of participants’ identity as an engineer, and ability to find and access their next steps within their pathway into engineering studies and careers. This included the importance of the program supporting participants to develop the artifacts needed to access next steps in academic and professional pathways, such as resumes, LinkedIn profiles, college application materials etc.

Implications for researchers

We invite the research community to explore efforts in program design, selection, evaluation etc, to add to our initial efforts. Further research into programs’ selection methods, and an evidence-based evaluation of such methods would be a beneficial area of further research. A wider literature review could provide the opportunity for deeper understanding of the factors that help and hinder underrepresented and non-traditional students accessing engineering outreach programs, including publications on K12-focused publications which provide a rich field of

information that would also be applicable, and further research to explore such commonalities would be a good direction for future research.

Implications for program designers and practitioners

Our approach in this research effort was to explore the actions and choices that were trialed in two outreach programs, framed in context of current literature, and expressed as a set of potential guidelines. This research effort aims to set foundations upon which others can expand, and evaluate their impact in different contexts, to add to this field of work. We invite practitioners to contribute with their own lessons learned from their experiences to ours which we brought forward as potentially helpful practices in this paper. Many factors go into program curriculum design that were not deeply touched upon in this paper, but that are critical to program inclusivity success. Topics such as program content, assessment and evaluation, would be good next steps in this research effort. The recommendations in this work aim to be easily adoptable, feasible, and to not require significant resources, having been designed to be suitable for use in resource-constrained efforts. For example, the infographic in Appendix 1 could be easily integrated into planning during the design of an outreach program, or the check-list used to identify small changes that could be adopted into an existing outreach program.

Impact of federal law on affirmative action on collegiate admissions

The recent end to the use of race-conscious affirmative action in college admissions programs, due to a change in federal legislation in the United States [33], will change how outreach programs recruit and select participants. This includes how they will represent their programs in advertisement materials, how application materials will be designed to help students express their unique identity, and how the program will communicate with, recruit, and make decisions on admitting program participants. In the wake of this, applications will focus more on student journey, barriers that have impacted their journey, and applications and admissions criteria will be adapted to utilize these factors rather than students' protected characteristics such as race, gender etc. The program staff in both case studies had all received training to address intrinsic bias through their employment in their higher education institutions. It is key to highlight the importance of collective viewpoints of selection, where no one individual holds the power of rejection or acceptance. Institutional support is crucial to ensure continued inclusivity in access to outreach programs, and these recommendations require administrators, designers and program staff to work together and share information about participants' experiences and needs, to help inform the backwards design approaches during iterations of program design.

Future work

This work aims to reduce barriers for marginalized students in accessing outreach programs by sharing best practices from two programs to ensure inclusivity and practical feasibility. While not within this paper's scope, future research could validate these recommendations using evidence-based methods, including student data analysis. Our next steps involve analyzing program content and evaluating its impact on participants' experiences and outcomes. This will include quantitative and qualitative research to assess participants' engineering identity, skills efficacy, progress towards education and career goals, and career trajectories. This will provide

further insights into evaluation processes and outcomes, aiding similar programs in enhancing their structure, content, and recruitment materials.

Conclusions

This paper aimed to explore effective practices for the equitable implementation and design of outreach programs in engineering higher education, which help overcome the barriers in recruitment, equitable admissions, and selection processes. We sought to answer the research question: ***How do you design recruitment, admission, and content for engineering outreach programs to increase access of marginalized and non-traditional students to such programs?***

The good practices explored in this paper emerged as common design and process strategies that were successful in reducing barriers marginalized and non-traditional students experienced in accessing the engineering outreach programs. While the exact "magic formula" needed to make outreach programs accessible, utilized and effective at increasing students' persistence, achievement and belonging in engineering is still a work in progress, this paper will be of interest to designers of similar engineering outreach programs that serve marginalized and non-traditional students in higher education – sharing program design practices can help provide a useful starting point. A printable list of each of the recommendations found throughout this paper are summarized in Appendix 2, and an infographic in Appendix 3 summarizes the key recommendations from the literature review and case studies, and is designed as a guide for program designers and institutions in the process of developing or improving engineering outreach programs for marginalized and non-traditional students.

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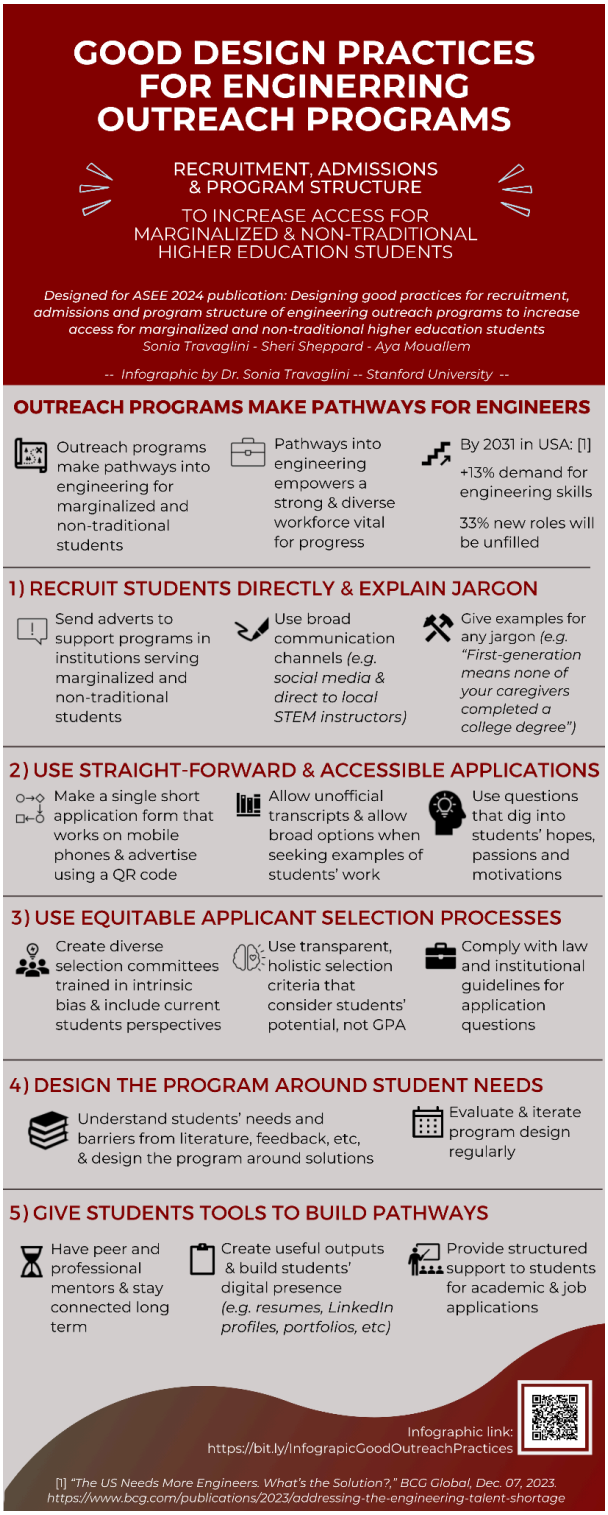
Appendix 1: Infographic summary of good practices for recruitment, admissions and program structure of engineering outreach programs to increase access for marginalized and non-traditional higher education students



Appendix 2: Checklist of good practices for recruitment, admissions and program structure of engineering outreach programs to increase access for marginalized and non-traditional higher education students

1. *Recruitment*
    - ☐ Direct recruiting from communities with a high population of marginalized students
    - ☐ Holistic application design and processes, such as students' GPA is not requested in the application, nor listed on the materials the program participant selection committee is provided with
    - ☐ Explicitly define terms that applicants may not have come across before, to remove a barrier of a 'hidden curriculum' by explaining speciality vocabulary
    - ☐ Advertise programs in the communication channels marginalized and non-traditional students are connected to
    - ☐ Unsuccessful program applicants were encouraged to apply again for the next cohort and to make use of other offerings, including mentorship programs, communications about other internship opportunities, and year-round engineering outreach-related events

2. *Application Design*
    - ☐ Design program application with questions designed to elicit students' curiosities, interests, and hobbies with connections to engineering, the information can be used to best match students to an engineering domain and mentor
    - ☐ Application questions designed to help applicants demonstrate their genuine passion for pursuing a career in technology
    - ☐ Questions in the application provide suggested guidelines for the length of responses, and describe the purpose and use of the information being sought
    - ☐ Use questions requesting brief but introspectively reflective answers, utilizing a non-formal tone in posing brief prompts for applicants to reflect on
    - ☐ Use application questions that ask applicants to reflect on setbacks and challenges that they've faced so far in any life domain
    - ☐ Provide simple examples for the questions that would encourage participants of any background
    - ☐ Program recruitment materials should be designed to address common barriers these students face, clearly indicating the financial, academic and logistical support available during the program
    - ☐ Designate a single individual as the program's designated contact person, so that applicants feel more comfortable asking questions or asking for support in the application process
    - ☐ Reduce financial barriers to students applying to programs (some of which may be less obvious than application fees, such as transport costs to attend interviews), can increase students' likelihood to apply
    - ☐ Accept unofficial university (or high school) transcripts
    - ☐ Charge no application fee
    - ☐ Provide broad options to demonstrate sufficient English language proficiency

- ☐ Applications should be made easy to access, with QR codes linking to the application form provided on all program advertisements

3. *Applicant Selection Processes*
   - ☐ Have a selection committee with a broad membership helps ensure the reduction of intrinsic bias by having broad perspective and member backgrounds
   - ☐ Use applicant evaluation categories that help the selection committee determine the applicants' level of interest, passion and motivations, as opposed to pure academic achievements
   - ☐ Create holistic application design and processes: Applicants' GPA is not requested in the application, nor listed on the materials the program participant selection committee is provided with
   - ☐ Grade or GPA level is not used as a comparative criteria to select between applicants, only having completed any STEM classes or not, to widen access. Instead reviewing the titles of courses taken that indicate interest in engineering

4. *Program Structure Design*
   - ☐ Use of 'backward design' and student-centered program design as frameworks to develop the outreach program design, where the desired outcomes lead the process; first outlining the desired outcomes, expressing these as goals, and then designing the activities and experiences to meet these goals, to help ensure the program activities, and evaluation of the outcomes, match the goals of the program
   - ☐ Document and publish program descriptions, goals, and outcomes
   - ☐ Align program goals and the measurement of outcomes
   - ☐ Center program activities on the development of academic and professional skills
   - ☐ Setting a goal of the program to increase students' level of knowledge and clarity around the engineering domain and career trajectory
   - ☐ Provide robust funding to program participants allowing them to focus on studies while being able to maintain external responsibilities
   - ☐ Program activities should support students in developing tangible artifacts to strengthen participants' access to pathways into higher education
   - ☐ Provide connection to community to encourage students to explore engineering identity and belonging
   - ☐ Incorporate ice breakers into program sessions, in addition to funding in-person meetups, to support community building
   - ☐ Programs should be designed to provide long-term professional development support for students, well after they have completed the program, ideally through to early-career stage to maximize students' persistence in education and pathways to engineering careers
   - ☐ Use iterative program design informed by multiple perspectives on program evaluation, so lessons learned from prior iterations guide the development of more successful future programs, and report information about the implementation of the program
   - ☐ Offer flexible employment hours to empower students from diverse backgrounds

- ☐ Provide support to navigate academic and professional landscape
- ☐ Provide long-term professional development support
- ☐ Create individualized research project design based on participants' unique skillset and academic trajectory
- ☐ Assign each participant is assigned to a mentor to support the creation of internship and academic application materials, and support to explore career interests
- ☐ Offer pre-program and post-program surveys to explore the influence of the program on the participants

Appendix 3: Literature review search terms

The list of search terms utilized for the literature review using Google Scholar, an online search engine for scholarly literature across an array of publishing formats and disciplines, is detailed in the list below. Analogous search terms were included, used to capture papers that fit within the scope but used different but similar descriptions. such as “structure” as a synonym for “design” of outreach programs. Similarly, the search resulted in the adoption of “transition” and “bridge” search terms used to describe programs designed for post-K-12 students in the process of transitioning into four-year college programs. Some search terms were combined with quotation marks “ ” to require an exact word match such as “engineering”, and some were combined with search operator characters to exclude or improve results, such as “ - ” to exclude these terms from the search results such as “K-12”. “Engineering” was also treated as having a wide definition, including broad fields of technical and academic disciplines such as mechanical engineering, computer engineering, and bioengineering, among many others. While the context of this paper and the case studies analyzed focus on aerospace engineering and computer science engineering disciplines, the literature review was not limited to these domains, to maximize the available range of applicable information available on beneficial outreach program design practices.

List of Literature Review Search Terms

1. Engineering
2. Engineer
3. Student
4. Outreach
5. Transition
6. Bridge
7. Persistence
8. Barriers
9. Needs
10. Underserved
11. Under-served
12. Marginalized
13. Pre-college
14. First year
15. Design
16. Program design
17. Practices
18. Structure
19. Framework
20. -K-12
21. -K12
22. -high school
23. -middle school
24. -high-school
25. -middle-school