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Good evaluation practices for community college engineering outreach programs

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Good evaluation practices for community college engineering outreach programs

Abstract

This Complete Evidence-based Practice paper details good design and implementation practices for the evaluation of engineering outreach programs specifically designed to serve community college students with the goal of sharing good practices that were found to be helpful in understanding the outcomes of the program for the participants, and the assessment of the efficacy of the program itself.

After students are recruited to and participate in engineering outreach programs, it is crucial to continuously assess their needs and experiences during the program, as well as to assess the effectiveness of the program activities designed to address these needs after the program ends. Evaluating how the program's activities, resources, and materials impact its participants is essential for stakeholders to determine whether the students are receiving adequate support, whether the content effectively serves its intended purpose, and to guide informed decisions for program enhancements. This paper explores the design, implementation processes, and materials used for program evaluation, through considering an example of an engineering outreach program for community college students, the Aeronautics and Astronautics Community Research Experience (AACRE) program, implemented in the Aeronautics and Astronautics department at Stanford University in the United States.

The function and efficacy of the program's designs, processes and materials were considered to extract a set of good practices for the evaluation of higher education engineering outreach programs designed for community college students. The work identified how objective evaluation of all program aspects, including the outcomes of participants, stakeholders and the program itself uncover rich sources of improvement that drive program enhancement. Pre-program surveys help identify and tailor program resources to participants' and stakeholders' needs and should be designed to be accessible and jargon free. Post-program evaluation should include both formal and informal methods. Formal methods include surveys, department-level and institutional-level meetings, and evaluation of the program and participants' outcomes using quantitative metrics. The metrics should be informed by the goals of the program and participants, such as measuring the change in engineering skills efficacy, and standardized to enable year-to-year program comparisons. Informal methods such as check-ins and 'watercooler chats' yield rich sources of anecdotal improvements that may not be otherwise captured in formal feedback mechanisms. The evaluation data are valuable for demonstrating the program's impact, and should be used for program promotion, and to communicate the value the program offers to both potential participants, and to stakeholders including the institution supporting the program.

This work will be of interest to similar engineering outreach programs designed to support community college students, by providing insights that can help enhance and inform their program evaluation design and implementation.

Introduction and Motivation

Engineering outreach programs in higher education are vital for promoting inclusivity and creating opportunities for marginalized students to explore and access engineering careers [4]. Increasing the representation of diverse and underserved demographics in engineering remains critical to addressing the growing shortage of engineers in the United States. Collaborative efforts between research universities and institutions serving large populations of underrepresented students play a key role in mitigating this shortage [5], supporting students to progress from two-year community college associate's degree programs, to four-year bachelor's degree programs. Expanding participation is essential not only to sustaining overall engagement in engineering as an essential industry, but also to driving innovation across the United States [6], [7], [8], [9], and for meeting the growing demand for engineering skills [10].

Engineering outreach programs are a key feature of the pipeline that supports marginalized students to connect with pathways that lead towards four-year bachelor's degree programs, and subsequent careers in engineering. They provide access to the knowledge required to find and connect to engineering degree programs, and help students develop the technical skills and associated artefacts of them that demonstrate their academic and practical abilities. For example, outreach programs may help students develop an online portfolio of engineering projects they have completed, to evidence their potential to undergraduate programs in four-year institutions. This is especially important for students attending community colleges who are aiming to transfer to four-year degree programs, and who may not have the resources or experience necessary to successfully find, connect to, and navigate educational opportunities.

Community college students may also experience other factors that may affect their pathways into engineering, including being first-generation college students, and/or being members of historically underserved or marginalized populations. Community college students benefit from tailored outreach programs that offer additional knowledge and guidance to connect to engineering programs and career opportunities in higher education. This can include knowledge of engineering career trajectories, and the artifacts needed to connect to opportunities, such as resumes, example projects, and online career profiles like LinkedIn. Engineering outreach programs also provide an essential connection point to the 'hidden curriculum,' knowledge [11] necessary to be successful in applications to academic or industry opportunities, such as the specialist vocabulary and tone customarily used to represent skills and abilities to engineering academic programs and industries.

Once students are recruited into engineering outreach programs, ongoing processes to further understand their needs, experiences, and the ability of the program activities designed to meet these needs, are critical to being able to assess the program's efficacy and outcomes. Understanding the influence of the program's activities, resources and materials on the program participants is essential for the program's stakeholders to be able to determine if the participants are being well supported, if the program's content is being effective in helping the students they serve, and for use in making informed decisions on program improvements.

A significant challenge students face within this pathway is their lack of experience and limited access to resources, which hinders their ability to effectively present their academic expertise and

broader potential to outreach programs that can help them along their journey to a degree program. This is often due to a lack of familiarity with how such information is interpreted and evaluated within outreach program admissions, placing these students at a disadvantage of being accepted - despite being the very individuals these programs aim to recruit, admit, and support. This issue is tied to the concept of the "hidden curriculum" which refers to the unspoken expertise and norms that are not immediately apparent to students [11]. The hidden curriculum includes the implicit approaches, values, and vocabulary communicated to students unintentionally [12], which form part of the cultural values and standards common within engineering disciplines. While these lessons are not explicitly made educational objectives, understanding and navigating them is crucial to students' academic and professional success [13]. Engineering outreach programs help provide the mentorship needed for students to access this hidden knowledge required to successfully communicate and demonstrate their mastery of academic and practical skills in engineering. For example, outreach programs can help students craft their personal statements used for academic program applications, in the vocabulary and form that best meets the expectations and assessment metrics that programs use to evaluate students' potential for admission to such programs, widening access to engineering degrees.

Background

Founded in 2021, the Aeronautics and Astronautics Community Research Experience (AACRE) outreach program aims to assist marginalized and non-traditional community college students in accessing pathways in engineering higher education, while also meeting the need for diversification in admissions and engineering career pipelines. The 10-week summer program is built around a research project, designed to enhance participants' skills and understanding of engineering and research methodologies, project implementation, and technical and persuasive communication of the project outcomes. Developed within and supported by the Aeronautics and Astronautics department at Stanford University, it is constructed around student-centered design principles, putting the needs of the participants at the center of how they are served to help remove barriers. For example, to address financial and technological barriers, laptops are provided to the participants to remove the cost they would face in ensuring they have a computer able to run the software they may need to complete their research project within the program.

Alongside technical skill-building, the participants are also supported to develop communication skills such as presenting and science writing, and are provided with peer mentors who help share implicit hidden curriculum knowledge. A goal of the program is to also boost students' confidence and sense of belonging within engineering, as both are key factors in the persistence in students pursuing engineering studies [1]. A program capacity for two students annually ensures robust funding and individualized support for the participants, including post-program career support by program staff. To date, all eight participants of prior years have successfully transferred to engineering four-year degree programs or further studies.

General Program Evaluation Approach

The program evaluation design and processes for the AACRE program were designed to seek information at several phases from participants and a variety of stakeholders in the program,

including Stanford University as an institution, departmental staff, mentors, and participants. Alongside processes to draw out information from the participants, evaluation of the program also seeks and supplies information to inform key stakeholders throughout the annual cycle of the program, to aid ongoing support and funding. The evaluation process design was informed by the design methodology of a continuous improvement feedback cycle [2], constructed from an iterative loop of seeking information, analyzing opportunities to address shortcomings and increase successes, and implementing these improvements. The evaluation methodology design was partially informed by outcome-based assessment practices used within education disciplines [3], and partially organically developed as the program design has iterated annually, improving the evaluation processes themselves each year. Within the AACRE program, as shown in Figure 1 below these methods. Those are implemented by seeking feedback alongside assessment of the program using a set of metrics, reflection processes to analyze how these insights can inform program improvements, and iterating these into the design and implementation of the next year.

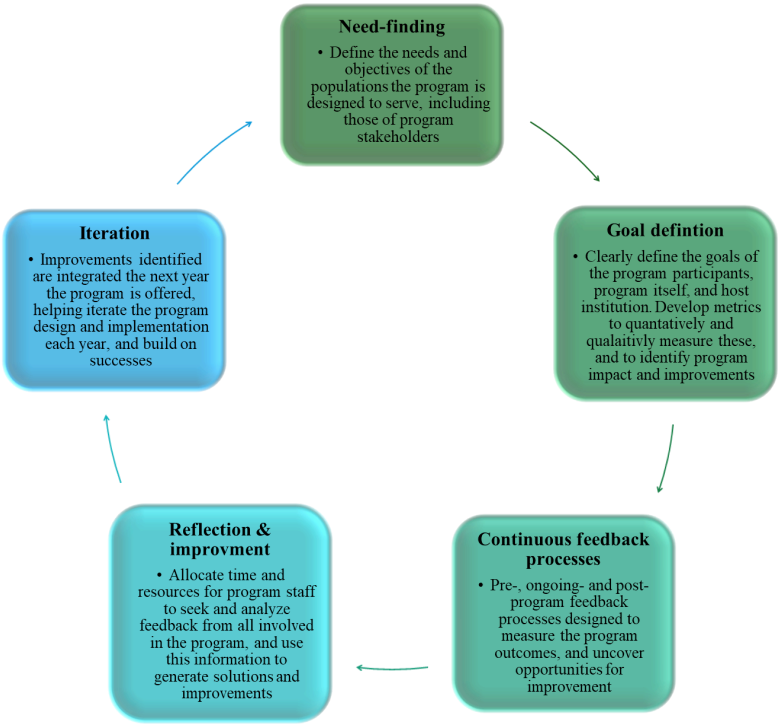

Figure 1: Iterative evaluation process design to generate and implement improvements for an engineering outreach program in higher education

Past work by these authors on the same outreach program used in the example of this paper, has focused on how informed design and implementation of outreach programs can help reduce barriers to marginalized students . These include both conceptual barriers, such as hidden curriculum knowledge [14], and practical barriers, such as the time, financial cost [15] and logistical demands students face in connecting to and attending such programs. The work highlighted the benefits of various program design approaches as a model to develop the outreach program, including ‘backward design’ and ‘student-centered’ program design. ‘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 [16]. These design methodologies help align program activities

and evaluation of the outcomes, to the goals of the program in serving students. Similarly, a student-centered program design, where the needs of the student become the core values to which the program is designed to meet, ensure the program design fits and develops with the needs of marginalized students, reducing barriers and increasing rewarding experiences and the benefits they gain [17] since their needs can be significantly different from other student populations.

The prior work highlighted the critical importance of the design of engineering outreach programs reporting and evaluation processes, so that the lessons learned from prior iterations steer the development of future programs. This includes the recommendation of using iterative program design, with program reporting and evaluations processes that cyclically seek and leverage multiple perspectives including those of student participants and other stakeholders, which are then used to redesign the program to best serve the students' needs. This was the motivation for this work – to explore good practices for the evaluation of higher education engineering outreach programs designed for community college students.

This paper will supply recommendations for program evaluation that foster inclusive practices that actively engage students and stakeholders - shifting the focus from representation as an end goal, to meaningful inclusion. Importantly, access alone is not synonymous with inclusion. As a student's self-identity plays a significant role in their retention within engineering education and careers [18], outreach programs must consider how they define and support diverse populations to effectively address their unique needs. While defining marginalized and non-traditional students can be complex, this paper defines marginalized students as those historically and currently excluded from engineering. Throughout this paper, the terms "marginalized" and "underserved" are used interchangeably. This definition of marginalized includes individuals whose experiences intersect across various identities—such as race, culture, socioeconomic status, and citizenship, that result in compounded challenges due to interlocking systems of oppression [19]. This definition also encompasses students who face barriers despite not meeting traditional definitions of marginalization, such as First-generation and Low-Income (FLI) students, as well as students returning to education, who may experience barriers despite not neatly fitting standard definitions of being "marginalized".

Positionality

This work is offered from the positionality [20] of the researchers at Stanford University, examining an outreach program situated in the United States, and from the perspectives of the designers and agents of an engineering outreach program that exclusively serves marginalized students. The contributing authors all 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. The authors have various perspectives on higher education, ranging from recent graduates to faculty, but all have a commonality of interest in engineering pedagogy and conducting research on how people become engineers. Their motivation to share insights includes their long history of engagement with marginalized students and observations of inequities, and their own personal experiences in education. Along with a personal motivation to support community college students to find pathways into higher education in engineering, the first author worked with the Aeronautics and Astronautics

department at Stanford University to develop the AACRE program used as an example within this work, and serves as the staff member to organize and manage the program each year including being a program supervisor for the participants. These positionalities inform how the authors elicited insights and practical opportunities related to improving students' access and experiences within engineering.

Methods

Identifying the practices that proved valuable in understanding participant outcomes, helped assess the program's overall efficacy, and supported a process of iterative program improvements was achieved by examining the:

- Methods used for the evaluation of the outreach program, including formal methods such as surveys for the participants, and informal processes designed to seek feedback from program stakeholders.
- Design of the pre-program and post-program surveys for the student participants, with a particular focus on the design and accessibility, and use of both quantitative and qualitative questions to measure the program and participants' outcomes.
- Metrics used to determine the degree of program success, and the design of these metrics to best capture the impact of the program on participants, such as measuring engineering skill self-efficacy, and the program itself, such as the number of students successfully transferring to 4-year degrees or further studies.
- Feedback from Program Mentors (PMs) who supervised student projects, both pre-program to ensure optimized matching of participants and mentors, and post-program to generate improvements identified from unmet participant needs addressed by mentors.
- Program materials supplied to and used to gather information from participants and program stakeholders, and best practices for information used within them, such as using partially de-identified application materials used for admissions decisions.

Exploring Good Practices For Engineering Outreach Program Evaluation

Linking Outcome Measurement to Program Objectives

The core of the outreach program evaluation methodology is driven from having a clear definition of the program objectives, continuous feedback during implementation, and impartial assessment of final outcomes. Quantitative and qualitative metrics help ensure the program is objectively assessed, measuring the engagement with or completion of the program objectives, and in the specific and highly individualized objectives, such as 'learn to code Python', which are generated by the participant and program staff in collaboration during the on-boarding to the outreach program. This approach ensures both the program objectives, such as 'developing participants' engineering technical and soft skills', and the participants' student-defined objectives are equally evaluated. The outcomes of both types of objectives are tracked during the program using metrics that help quantize or describe the degree of completion, such as the participant rating their confidence level in coding Python pre- and post- program. **This outcome-based evaluation method forms the basis of measuring program outcomes and**

achievements, with the resulting insights used to iteratively improve the program. Metrics also provide concrete evidence to communicate the program outcomes, successes and the value it offers to the institution and potential participants, and to help drive program buy-in from stakeholders. For example, the AACRE program communicates the numerical percentage of participants' who achieve their planned academic or employment next steps, and describes the pathways as participants' progress to post-program, as key information for program advertisements to potential participants and to the program sponsors.

Table 1 below identifies some of the objectives of the AACRE program, the tracked outcomes used to evaluate them, and quantitative or qualitative metric used to objectively measure them:

Table 1: Program evaluation metrics developed from objectives and tracked outcomes

Program Objective	Outcome Tracked	Evaluation Metric
Develop participants engineering technical and soft skills	Participant self efficacy at a variety of ABET-informed engineering skills	Likert-scale participant self-assessment of confidence level in each skill, pre- and post-program
Create artefacts to demonstrate participants engineering skills	Creation of a project technical report, project poster, resume, and LinkedIn profile	Survey based yes/no questions for existence of each artifact, pre- and post- program
Introduce participants to engineering academic pathways and careers	Participants' level of interest in engineering, and intended next academic program or employment opportunity	Open-ended survey questions on the participants' level of interest in engineering, and current program/employment
Support participants to navigate academic and professional engineering environments	Participants' engagement with 4-year degree program transfer applications, and/or engineering employment opportunities	Direct communication with participants' post-program to determine pathway outcomes using open-ended questions

In addition to impartial measurement of the program activities and associated degree of success in them, the next most **critical evaluation method is seeking information and feedback about the program as it unfolds**. Seeking feedback from all parties involved, including the participants themselves, through to the institution itself that the program is embedded within, provides the richest source of improvements sourced from a variety of perspectives. For example, in the AACRE program, participants are asked to share about unmet needs, which are then used to inform what resources to offer within the next iteration of the program. For example; a participant identified needing more help to create a LinkedIn profile - and the institution shared its need for the program to have participants communicate the value and impact of the program to them. This feedback was analyzed to find an opportunity to meet both these needs; arranging workshops for participants to develop a LinkedIn profile, and support to create content that fits the strategic communication goals of the (AACRE) program itself, then shared with various engineering and academic communities.

Survey Design For The Evaluation Of Engineering Outreach Programs

The most important source of information for the AACRE engineering outreach programs for community college students, for the goal of improving and serving the student participants best, is sourced from the students themselves. Program stakeholders, providers of indirect and direct services to participants, and wider members of the institution the program is embedded within, all also supply valuable information and perspectives that can be used to inform iterative program improvements. The experiences, successes and needs of the students are the most critical part of informing iterative program improvement processes to tailor all aspects of the program; from the materials used to advertise the program, to the services offered to participants after completing the program. Within the AACRE program, seeking these student-informed information, perspectives and insights, is completed using pre- and post-program participant surveys. The full pre-program survey questions implemented during the on-boarding of participants can be found in Appendix 1, and the post-program survey in Appendix 2.

The pre-program survey explores a variety of information from the on-boarding participant, seeking to understand their:

- Program goals: Academic, practical engineering project, personal aims, and specific program objectives the participants hope to achieve during the program
- Need-finding:
    - *Career* - exploring the participants' current studies, interest level in aerospace engineering, and current career and academic plans
    - *Engineering skills and abilities* - confidence in the ability at a variety of engineering skills such as design, problem solving, troubleshooting etc
    - *Career and soft skills* - technical writing, communication skills, and soft skills such as networking.
    - *Logistical and technological* - access to a laptop/computer with sufficient hardware and software capabilities to meet the needs of the research activities of the participant, transportation needs, etc
- Demographic and logistical information: Confidential information required for on-boarding processes, and optional information relating to demographics and identities.

The **survey information is used to compare between the pre- and post-program survey, to determine the impact of the program on participants' career interests and plans, and change in confidence levels in academic, practical engineering, and soft skills**. The questions are designed to identify common needs the program has previously found the participants need to be successful; these are informed by the evaluation processes and each years' post-program survey, to identify barriers and needs participants' experienced, which the program can then use as a guide on what resources to offer. For example, when participants indicated needing support with "Writing academic references", this resource option then added to the need-finding survey of the next year's program, and a guide on how to reference academic information was added to the program repository of resources. The results of the **pre-survey need finding are used to match the resources available in the program to the academic and personal unique needs of each participant**, as shown in the following question from the pre-program need finding survey:

Question 20: Are there any technical topics you would like extra support with? (e.g., Math, technical writing, coding, etc)

The survey also offers optional questions to understand the participants' identities, in terms of both demographics, federally-defined identities, and identities relating to participants' characteristics of being marginalized, including First-generation and Low-Income (FLI) identities. **Survey questions relating to demographic information and identifies such as race, gender, etc, should be carefully designed to meet any legal requirements**. The 2023 U.S. federal legislation effectively eliminating affirmative action for college admissions [21] impacted what identity questions can be asked, and 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, based on race or ethnicity (and other protected characteristics, including disability, sex, sexual orientation and gender identity) [21], in order to address historical inequalities in college admissions and retention. **Survey questions relating to legally protected identities must be clearly noted as optional to disclose**, and are only used to determine the best tailored resources to offer participants, and not used to applicant selection processes. **Any information resulting from surveys relating to legally protected identities must also be appropriately processed and stored, so that confidentiality legal requirements and additional good practices are met**. For example, the program staff all received training to address intrinsic bias, including methods during application decisions such as using partially de-identified application materials used for admissions decisions.

Surveys should be carefully designed and marketed to the participants to help them to be able to fully engage, and determine what information to share. For example the pre- and -post surveys both **clearly explain the purpose of the survey seeking to understand their needs, to use this information to allocate resources to them, and its use in a de-identified format to help improve the program**. It also **explicitly states the confidentiality limits, for both identifying information, and non-identifying information** such as participants' opinions and perspectives. Along with the required informed consent for completing a survey, this practice reassures participants that their feedback will not be communicated to program staff that provide direct services, such as the mentors of projects the participants complete. This is important to **solicit honest and candid feedback on both positive and negative experiences within the program - as understanding negative experiences provides the richest source of program improvements**.

Any jargon within the survey must also be clearly defined and explained, with an example provided so that participants can evaluate for themselves whether they fit the definition of the information being sought. For example, an important design feature that ensures participants are able to interpret, understand and thus determine if they define themselves as belonging to identities such as FLI, is explicitly defining what 'first-generation' and 'low-income' means, and providing examples. The wording of these definitions should be given in plain language, such as defining 'first-generation student' meaning the completion of a degree by participants' parents', not just partial completion. In the AACRE pre-program survey, these questions include a plain language definition to explain and give example of any jargon, such as:

Question 27: "Are you a first generation college student?
(Meaning your parent(s) / caregiver(s) have NOT completed a bachelor's degree)

These small but significant details are important to explain, so that participants who are not well-versed in higher education jargon do not mistakenly misclassify their identities to their detriment of not being provided with resources specifically designed for them, such as for first-generation students. This is important as student persistence, meaning completion of a degree [22], is a greater barrier for marginalized populations, who may be successful in enrolling in higher education but ultimately lack the resources and support to complete the degree [23]. For example, the survey questions designed to assess engineering skills were expressed in plain language in the survey, reducing the jargon into more accessible descriptions; such as summarizing an ability to '*...function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objective*s' as '*collaborate with others*'. **Surveys should consider common identities that impact marginalized students' access to engineering studies and careers, and ask questions in plain language with examples to help participants understand if they consider that these identities apply to them**.

Measuring Participants' Self-Identified Skills and Abilities

To understand the participants' pre- and post-program skills and abilities, a standardized set of questions is used within surveys, informed by the ABET Criteria for Accrediting Engineering Programs, Criterion 3. Student Outcomes [24], such as being able to apply new knowledge, solve complex problems, and communicate and work effectively in teams. The questions informed by the ABET criteria help explore a variety of technical and soft skills participants use and develop during the program, alongside questions developed from previous program feedback, such as the ability at '*asking questions*' (found from previous program year's participants' feedback to be a useful skill they developed within the program). The questions are used to assess change in the confidence level of the participants pre- and post-program, to determine the efficacy of the program in developing these skills and abilities. Similarly, the participants' level of interest in aerospace engineering, and planned future studies and careers in engineering, are compared pre- and post- to determine the program's impact on the participants' likely academic and career trajectory within engineering. The confidence level used as the metric is measured using a Likert scale of 1-5 indicating from '*5 - Very confident*' through to '*1 - Very unconfident*' [25]. This method was chosen as it provides an accessible method for participants to intuitively classify their self-assessed perception of their ability at the skill - rather than their perception of the practical outcome of applying the skill itself. This helps capture the impact of the program on participants' ability to take forward the knowledge and skills they develop during it. The data collected is then analyzed to identify program impact, and to determine improvements to further increase it. As an example, in the AACRE outreach program the participants' quantitative data from the surveys exploring self-efficacy in engineering skills was analyzed to compare the responses between the pre- and post-program surveys for the two participants in the most recent year of the program in 2024, as shown in Figure 2.

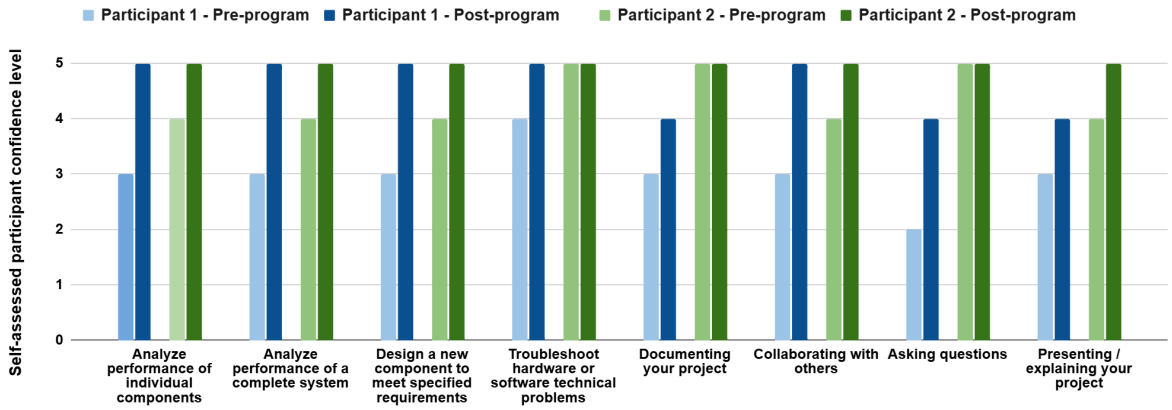

Figure 2: Example of quantitative program outcome measurement communication

The comparison of participants' pre- and post-program self-efficacy in engineering skills in Figure 2, demonstrated how the confidence rating for the majority of skills is measured, and how this can quantitatively communicate the positive impact of the program on the participants. The analysis showed that the two participants determined their self-efficacy to increase by at least one level of confidence in their ability at engineering and other skills during the program. As each program participant and their incoming skill set and abilities are unique, the **pre-program survey helps identify the skill level of each individual joining the program, helping tailor program content to the unique abilities to a broad range of incoming skill levels**.

Similarly, using the survey to identify and compare participants' pre-program predicted needs of program resources, and post-program actual use, helps determine which resources were highly utilized and could be increased. Figure 3 below shows the qualitative visual method used to compare participants' expected and actual resource use. For example, participants did not expect 'documenting work' as need of support pre-program, but post-program indicated it was highly utilized, resulting in the program increasing support and resources for how to document work.

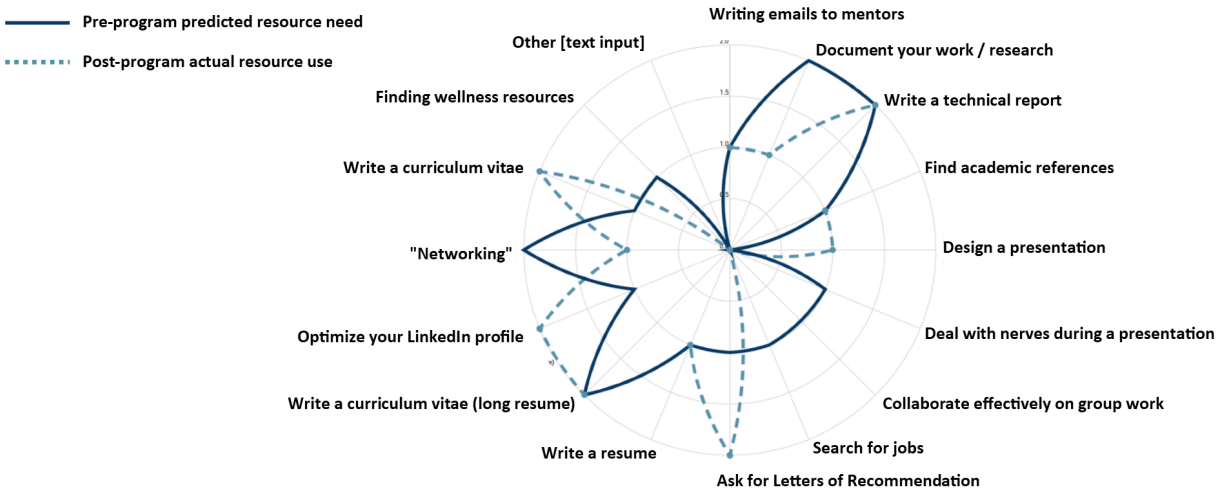

Figure 3: Example of qualitative comparison of program resource predicted and actual use

Measuring Program Success to Inform Program Implementation and Improvements

Alongside active feedback gathering and evaluation processes for participants, the **program itself should be objectively assessed using a set of standardized metrics, to enable information gathering about the current program activities, and to enable year-to-year comparisons of the program to identify the impact of improvements**. In the AACRE program the following metrics are measured annually[SDS1]:

1. Outcomes of research project activities and progress, such as the number of artifacts created by participants and stakeholders, including any academic posters or publications, presentations or other artifacts
2. Logistical information, such as the average number of hours participants' invest in their project work and program activities, and number of times that participants made use of provided resources such as career services
3. Belonging and community involvement, such as the number of times participants' attended supportive activities and social events
4. Program outcomes, including career trajectories and academic or employment successes

Program evaluation metrics, which form the **key measures of information about the outreach program's outcomes and impact, should be shared with stakeholders**; such as an update on the program success during a faculty meeting. **Feedback on participants' successes should also be used to strengthen links to the community colleges the participants are recruited from, communicating the value of the program to the students they serve**. For example, the AACRE program conducts short presentations about the successes and career developments of past program participants to the local community colleges where the program often recruits participants from. **Using quantitative measures and information about the program's impact supports efforts for the ongoing funding and resource allocation to the program, and also helps communicate the value of the program in advertising aimed at potential participants.**

The outreach program also uses a stakeholder survey [SDS2] to invite and identify the suitability of potential research Project Mentors (PMs) from departmental faculty, who have research groups with capacity to support a program participant. The **survey explores research groups' topics and projects, to help match the mentor and group focus to the interests expressed by the program participant**. The survey also explores the availability of support resources, such as peer mentors at the graduate and postdoctoral level, and a research or laboratory group working philosophy suited to scoping research projects to fit a community college student level. The survey also explores the research or laboratory group culture, which must be experienced in inclusive mentoring practices of marginalized students, and capable of supporting and guiding community college-level students who may not have had any previous experience within a research institution, group, or project. This is a critical part of the participants' having a successful experience, as strong peer and research group support and mentorship was often identified by both program participants and PMs to be key in helping the participant to develop their skills, feel supported, and also to enjoy their time within the program.

Along with the pre- and post-program surveys for participants and stakeholders, **regular informal check-ins with past program alumni are completed, to seek information about**

their current engineering academic and industry activities, and career trajectories. This information is critical in the communication and promotion of the program's value and outcomes; the next studies, engineering internships, and eventual transfer to a four-year degree program is tracked and reported to the institution and used for promotional purposes. For example, program advertising materials feature that 100% of past program participants have progressed to 4-year programs or further studies within engineering. The outreach program was designed to ensure that once participants complete the program, they are supported to actuate the plans they developed during it, including for their next academic studies. They are supported by peer mentors and program staff in the process of their applications to transfer to four-year degree programs, particularly in how to effectively describe the technical and academic skills they recently developed in the program, which help them be competitive and successful students in their next studies. The program also seeks regular updates about past participants' pathways within the engineering industry, such as in internships that help them develop the technical skills and artefacts of these, which are most valuable for them in their pathways into engineering as a career. Reciprocally, the program **alums experiences and knowledge of the current state of academic and industry disciplines, and the latest hidden curriculum information within those, is sought out by the program and used to inform the resources provided to the next generation of program participants**.

Leveraging Stakeholders Input to Identify Program Improvements

In addition to the information sought from and about participants', and the program itself, another vital source of information is the program's PMs. These faculty and graduate students, who support the participants to complete their practical research projects during the program, have rich information on how to better serve participants. This is sought using both formal and informal mechanisms. Formal methods include seeking feedback from stakeholders at department-level and institutional-level meetings, such as monthly faculty and administrative meetings. This helps **uncover valuable hidden feedback from various stakeholders, who may or may not be directly involved with the program or participants, and have useful sources of improvement or additional value to offer the program**. For example, after inviting comments about the AACRE outreach program during an administrative meeting, staff indirectly involved with the program noted that in addition to serving the participants with institution-level Human Resources support, they could also share valuable insights into their own careers, sharing about pathways focused on administrative and learning support roles within academia. This led to the program improvement of inviting participants to a departmental administrative meeting once during the program, so they could observe and connect with various careers in academia, and experience the wider academic setting they are embedded within during the outreach program at Stanford University. **Informal feedback mechanisms are also valuable to seek small 'gems' of casual information that are anecdotal, which provide rich sources of improvements that may not be otherwise captured in formal feedback mechanisms**. For example, short 'watercooler' chats with PMs can help solicit useful insights about program successes and challenges, and provide a way for PMs to provide feedback without a heavy time burden for contributing such information.

These insights are valuable sources of program improvements, both of processes or resources to add, and of barriers and sources of challenge the participants' experience. The perspectives of the

PMs help generate improvements that are practical within the context of the program, as the PMs are well-situated to assess these in the context of the academic environment - and how participants' level of ability will impact their efficacy. For example, feedback in 2023 identified that participants' needed additional support to navigate sharing about their project progress at research meetings within the PMs laboratory group. An improvement was introduced in the 2024 program year, providing participants' with a short template of what information to share at group meetings (such as recent results, areas where support is needed, etc), and a description of the format and norms of such meetings. Informal feedback from the PMs during the 2024 year found this improvement helped participants to further engage and participate in research meetings.

Summary of Good Practices for Engineering Outreach Program Evaluation

As part of the evaluation of the AACRE program during each years' iteration of the program, the following evaluation good practices were found to help generate rich feedback on the program, both from participants and stakeholders, and proved useful in finding program improvements:

Pre-program need-finding and norm setting:

- Implement a **survey designed to understand the interests, goals, and needs of the program participants** to help inform program content as they on-board - these are also used to evaluate the outcomes and impact of the program, during and after.
- **Tailor the program content, delivery and resources to each participant** to help the program meet each unique set of needs , such as helping participants create LinkedIn posts about their project, or support to establish a profile if they do not have one yet
- A**rrange a 'kick-off' meeting with the participant, PM and any peer mentors, and program staff, to support participants to set project goals and objectives, plan meeting cadences, and set norms and expectations**. This helps create a structured program experience and also serves as an opportunity to make the implicit professional etiquette of the group explicit, such as the expected working schedule and culture.
- **Invite the participants to all departmental events, both formal and informal, and seek feedback on how these helped serve or support them**. This also helps engage participants in the program and the wider academic environment - ensure a PM, program staff or peer mentor also attends, to help structure the experience and introductions.
- **Build in pre-program operational processes, such as securing funding, administrative approvals, and logistical planning activities** with various departmental and institutional stakeholders, in a regular cycle ahead of the program

Ongoing feedback processes:

- **Maintain strong collaboration with institutional administration**, such as Human Resources and other operational services, to ensure the program stays compliant with institutional policies and requirements
- **Coordinate meetings with the participant, the PM and/or their research group**, to support participants to share ideas, updates on progress, and seek support
- **Require regular research progress updates and meetings with participants and program staff** to assess the evolving needs of participants during the program
- **Provide project and program tracking document templates**, so the PMs and the

participants are supported to track progress and needs, plan ahead, and reflect
- **Promote program activities and outcomes with the department and institution to share successes and help generate engagement**, such as inviting faculty and students to any presentations by the participants

Post-program reflections and leveraging outcomes:
- Implement a post-program participant survey exploring the successes and challenges they experienced, both within the project and the program
- Create formal and informal feedback processes for PMs, peer mentors and other program stakeholders, to identify program improvements
- Encourage participants to give candid feedback to help inform program improvements
- Connect with program alums to stay informed about participants' achievements
- Communicate participant and program outcomes post-program with stakeholders, including qualifying success using evaluation metrics where possible, such as sharing participants' increase in skills or other achievements

Conclusions

Through considering an example of an engineering outreach program implemented in the Aeronautics and Astronautics department at Stanford University, the good practices that proved valuable in understanding participant outcomes, assessing the program's overall efficacy, and which supported iterative program improvements were shared. The design and implementation of evaluation processes were informed by a model of continuous improvement feedback cycle; forming an iterative loop of seeking information, analyzing opportunities to address challenges and increase successes, and implementing improvements for these for each year of the program. Understanding the needs and value of the program to the participants, and to the host institution is critical in finding program improvements, and communicating the impact and value of the program to the students it serves and the host institution it's supported by. Seeking feedback should be a continuous process, beginning during on-boarding, continuing throughout, and ending with reflections at the end of the program, by both program participants and stakeholders such as program and institutional staff.

Pre- and post- program surveys provide an essential instrument to understand participants' needs, objectives within the program, current state of their self-assessed engineering and soft skills, academic and career trajectories, and feedback on the program. This information is vital to understanding participants' needs and ensuring program content is tailored to them. Surveys which determine the career trajectories of participants, and their confidence in a range of engineering skills, help assess the impact of the program on participants, by the comparison of pre- and post- changes in participants' skill levels and career trajectories. Surveys also provide insights into the impact and value of the program, and help determine if the participants' and program's objectives were achieved. Informal and formal feedback from both participants and stakeholders provides rich sources of improvements for the next iteration of the program. Finally, the results of program evaluation, especially data from metrics relating to the development of participants skills and engineering career trajectories, should be communicated to the host institution to drive engagement and program promotion to stakeholders and future participants.

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Appendix 1: Pre-program participant on-boarding survey questions for an engineering outreach program in higher education

Personal information questions

1. Name
2. Contact email
3. Contact phone number

Need-finding questions

4. Will you need a laptop to use during the AACRE program? (We can loan you a laptop that has the performance to run CAD/computing intensive programs)
5. If the opportunity to work hybrid is available, do you have stable internet (eg for zoom calls) at your home address?
6. Do you have a webcam and microphone (eg, on your laptop?)
7. How will you be commuting to Stanford campus? (eg, bus, train, car etc)
8. Do you need any work accommodations? (eg, desk or work equipment adaptations for a person with a disability/neurodivergent/other needs)
9. Are there any dates during the program (Day/Month - Day/Month) you WON'T be available? (Just so we know in advance to schedule time-off for any important appointments, vacation days, community college exams/start of term appointments etc)
10. Are there any days / hours / weekly time slots you will NOT be available? (eg due to studies/non-work commitments - feel free to update Sonia if/when these change)

Educational information, skills, and program objective questions

11. What community college(s) are you currently studying at?
12. How many years have you been studying there?
13. What major/topic are you currently studying?
14. What major/topic do you plan to transfer to at a 4-year program?
15. What major/topic do you plan to transfer to at a 4-year program, and when?
16. What jobs (if you have any in mind) do you hope to progress to?
17. How interested are you in aerospace / aeronautics / astronautics? (Likert scale of 1-Not interested at all, to, 5-Very interested!)
18. How interested are you in graduate (Masters/PhD) studies? (Likert scale of 1-Not interested at all, to, 5-Very interested!)
19. Rate your confidence in your ability to do each of the following: (Likert scale of 1-Very Unconfident, to, 5-Very Confident!)
    Analyze performance of individual components // Analyze performance of a complete system // Design a new component to meet specified requirements // Troubleshoot hardware or software technical problems // Documenting your project // Collaborating with others // Asking questions //Presenting / explaining your project
20. Are there any technical topics you would like extra support with? (eg Math, technical writing, coding, etc)
21. Which of the following non-technical topics might be most helpful for you get get extra

support with? How to... (select all that apply!)
Address professors when you meet them / via emails // Document your work / research // Write a technical report // Find academic references // Write academic references // Design a presentation using Powerpoint/Googleslides // Deal with nerves during a presentation // Collaborate effectively on group work // Search for jobs // Ask for Letters of Recommendation // Write a resume // Write a Curriculum vitae (aka a CV, aka a really really long resume) // Optimize your LinkedIn profile for job hunting // "network" (aka, ask people for jobs/opportunities!) // Deal with stress / finding wellness resources // Other…

22. What are 3 personal goals for during the AACRE program? (Try to make them SMART [Specific, Measurable, Achievable, Relevant, and Time-Bound]

Optional identity and demographic questions

23. I currently identify with my gender as: Check all that apply (Agender, Man, Non-binary, Questioning, Woman, Prefer not to answer)
24. Do you identify as a person with disability/ies?
25. Do you identify as a veteran?
26. I currently identify with my racial/ethnic community as: Check all that apply: (American Indian or Alaska Native Asian or Asian American, Black or African American, Hispanic or Latino/a, Middle Eastern or North African, Native Hawai`ian or Pacific Islander, White or European, Prefer not to answer)
27. Are you a first generation college student? (Meaning your parent(s) / caregiver(s) have NOT completed a bachelor's degree)
28. Do you identify with being a Low-Income student? (Meaning you, AND / OR your family/caregiver(s), have a household income of less than $50,000 a year)

Open-ended question

29. Anything else to share? All comments / ideas / suggestions / thoughts / questions / shares welcomed!

Appendix 2: Post-program participant survey questions for an engineering outreach program in higher education

Personal information questions

1. Name
2. Contact email (that is available after the program ends)
3. Contact phone number (that is available after the program ends)

Intended pathway questions

4. What community college(s) will you be studying at in Fall 2024?
5. When do you plan to transfer to at a 4-year program?
6. What major/topic do you plan to transfer to at a 4-year program?
7. What jobs (if you have any in mind) do you hope to progress to?
8. How interested are you in aerospace / aeronautics / astronautics? (Likert scale of 1-Not interested at all, to, 5-Very interested!)
9. How interested are you in graduate (Masters/PhD) studies? (Likert scale of 1-Not interested at all, to, 5-Very interested!)

Educational information, skills, and program objective questions

10. Rate your confidence in your ability to do each of the following: (Likert scale of 1-Very Cnconfident, to, 5-Very Confident!)
    Analyze performance of individual components // Analyze performance of a complete system // Design a new component to meet specified requirements // Troubleshoot hardware or software technical problems // Documenting your project // Collaborating with others // Asking questions //Presenting / explaining your project
11. Which technical topics did you find helpful to extra support with? (eg Math, technical writing, coding, etc)
12. Which of the following non-technical topics did you find helpful getting support with? (select all that apply!) How to…
    Address professors when you meet them / via emails // Document your work / research // Write a technical report // Find academic references // Write academic references // Design a presentation using Powerpoint/Googleslides // Deal with nerves during a presentation // Collaborate effectively on group work // Search for jobs // Ask for Letters of Recommendation // Write a resume // Write a Curriculum vitae (aka a CV, aka a really really long resume) // Optimize your LinkedIn profile for job hunting // "network" (aka, ask people for jobs/opportunities!) // Deal with stress / finding wellness resources // Other…

Program and participant outcome evaluation questions

13. What would you have liked to have learned more about?
14. What were your project goals at the start of the AACREs program?

15. Rate how well you feel you achieved these project goals (Likert scale of 1-Very well, to, 5-Not at all)
16. What are some things that went great?
17. Which were the most challenging aspects of your experience?
18. How could we have made your experience better?
19. What were your 3 personal goals for during the AACRE program? (Feel free to copy and paste!)
20. Rate how well you feel you achieved these personal goals (Likert scale of 1-Very well, to, 5-Not at all)
21. How many hours a week did you averagely work with AACREs?
22. What proportion of your time with AACREs was ONLINE, and what proportion was IN-PERSON?

Optional identity and demographic questions

23. I currently identify with my gender as: Check all that apply (Agender, Man, Non-binary, Questioning, Woman, Prefer not to answer)
24. Do you identify as a person with disability/ies?
25. Do you identify as a veteran?
26. I currently identify with my racial/ethnic community as: Check all that apply: (American Indian or Alaska Native Asian or Asian American, Black or African American, Hispanic or Latino/a, Middle Eastern or North African, Native Hawai`ian or Pacific Islander, White or European, Prefer not to answer)
27. Are you a first generation college student? (Meaning your parent(s) / caregiver(s) have NOT completed a bachelor's degree)
28. Do you identify with being a Low-Income student? (Meaning you, AND / OR your family/caregiver(s), have a household income of less than $50,000 a year)

Open-ended question

29. Anything else to share? All comments / ideas / suggestions / thoughts / questions / shares welcomed!

Appendix 3: Infographic of good evaluation practices for community college engineering outreach programs