Work In Progress (WIP): A Systematic Review Describing Impacts on Engineering Undergraduates who Participate in Outreach

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Overview

To teach STEM content to K-12 students, and recruit talented and diverse K-12 students into STEM, many outreach programs at universities in the United States rely on the collective efforts of undergraduate students. Outreach design and research have typically focused on the K-12 students and their teachers, leaving the effect of the outreach on the STEM undergraduates themselves to be an important but overlooked consideration that has received less attention in the engineering education literature. This WIP paper describes the preliminary findings of a systematic review of literature on the impact(s) of involving undergraduates in engineering outreach with a particular focus on studies that report on the impact on the undergraduate students. Supporting this effort is the NSF EArly-concept Grant for Exploratory Research (EAGER) program.

Introduction

In response to the need to increase interest and persistence in STEM careers, many universities have created organized outreach initiatives. Engineering outreach by undergraduate students takes different forms but can include leading summer camps, teaching afterschool programs, conducting classroom presentations, and hosting engineering fairs and competitions on colleges campuses. The focus of evaluation efforts for K-12 outreach programs is typically on the ways in which students and teachers are impacted, but participation in K-12 outreach has also been portrayed as a means of improving undergraduate students' affective and motivational wellbeing, including their engagement, persistence, and personal identification with a subject area such as engineering [1]. Some scholars have argued that outreach participation, like other forms of co-curricular activity, provides students with a sense of community and belonging, increases resilience, and minimizes feelings of marginalization [2]. Others have emphasized that outreach participation can act as an opportunity for undergraduate students to develop critically important professional skills that might not otherwise be learned in typical undergraduate courses such as technical communication, teamwork, leadership, and the ability to integrate across engineering disciplines [3-4, 52]. In this systematic review of literature, we sought to better understand affective and cognitive facets of outreach impact and draw conclusions about the overall nature of research conducted in this area.

We used systematic review methodology to guide this work [5]. Systematic reviews treat individual studies as sources of data and involve a series of steps that are guided by research questions. After defining and executing a number of inclusion and exclusion criteria for the set of papers to be considered, common features of studies are extracted and compared with one another. Findings are typically reported using tables that organize the critical features of each study as well as via a narrative form that describes overall trends or findings. In this case, we used an aggregative synthesis approach, which is typically used to investigate questions about impacts or effects and reveal descriptive information about the state of the field from which directions for future research can be derived. Our three research questions were as follows:

1. What research designs are used to examine the impact of outreach on undergraduate engineering students?
2. What theories are used to examine the impact of outreach on undergraduate engineering students?
3. What themes emerge from studies' findings about the impact of outreach on undergraduates?

Method

The first steps were to develop inclusion and exclusion criteria for the review. Criteria for including the papers were fourfold: (1) describe programmatic outreach efforts from one or more colleges of engineering to K-12 audiences, (2) include undergraduate engineering students as ambassadors or mentors, (3) take place within the continental United States, and (4) include evidence of impacts on the undergraduate students. In other words, papers were excluded if they (1) described undergraduate involvement in service learning, affinity group, or community engagement projects, (2) included undergraduates simply as chaperones or creators of classroom activities, (3) described activities undertaken in overseas settings, and (4) did not report any impacts on undergraduate students conducting the outreach. Next, search terms were defined to cover our areas of interest. Three academic databases were searched using all three terms: engineering + undergraduate students + outreach. Records were retrieved for 1996-2018. The ASEE search revealed 3,403 records, and the ERIC and Education Research Complete searches revealed just 23 and 7 records, respectively. Using the search terms in a historical manner revealed a significant upward trend in the number of papers describing projects and research studies that involved undergraduate students in an outreach capacity. For example, whereas a search of the 1996 ASEE PEER database yielded just 14 papers, this number had grown to 124 by 2006 and 303 by 2016.

The large corpus of literature became much smaller once three of the four complementary inclusion and exclusion criteria were applied. Only 462 papers were eligible for an informational value assessment, which involved detailed reading and an examination of the quality of evidence provided under the fourth inclusion/exclusion criterion. Once again, a historical trend was evident; for example, only 3 papers being retained from the 1996 PEER archive, compared with 14 in 2006 and 82 in 2016. When examined using the fourth inclusion criteria, 48 papers were found to include primary qualitative or quantitative data from which claims were supported. These papers were then subject to critical feature extraction.

Several features of each paper were recorded. These included the authors of the paper and its year of publication, the institution(s) at which the outreach was taking place, the name of the outreach program, the outreach model and a description of any professional development or training received by undergraduates, the program's premise or underlying theory of action, the study purpose or research questions that guided the paper, the methods used to investigate impact on undergraduates, and the main findings in relation to the impact on undergraduates. Additional details about impacts on K-12 students or teachers were not recorded.

Findings

The critical features of each reviewed study are summarized in Tables 1a and 1b, which are organized by research approach. Studies investigating change over time are presented in Table 1a. Studies utilizing post-hoc responses are included in Table 1b.

Research Question 1. What research designs are used to examine the impact of outreach on undergraduate engineering students?

The two most common research designs included surveys of undergraduates in either a single-group pre-test/posttest design (n=10) or a posttest only design (n=31). Only one study included a comparison group in which outreach participation was compared with a comparison group of students who participated in an introductory engineering course instead. Most (n=31) of the studies relied on a survey with either Likert scale or open-ended questions as a form of data collection. Just two studies explicitly referred to the use of previously validated instruments. Five studies took a qualitative interview or diary approach. Several studies exclusively used non-self-report data sources including outreach logs, work products, observations, or undergraduate student retention data.

Research Question 2. What theories are used to examine the impact of outreach on undergraduate engineering students?

Since most of the papers did not implement previously validated measures, and very few included surveys or interview questions as appendices, we drew from the background sections of the papers to better understand the constructs and theoretical frameworks researchers used to shape their understanding of the impact of conducting outreach on the undergraduates. Most of the papers included a brief literature review, but only a small number of papers included an explicit theoretical perspective to frame how and why outreach might impact undergraduates. Many papers referred to general concepts such as peer mentorship, cohort-based learning, or communication and professional skills, but did not operationally define them in relation to explicit research questions or specific measures. However, in studies where this was apparent, we noted that one of four salient theoretical perspectives was evoked: (1) Valence, Instrumentality, Expectancy theory [6], (2) self-efficacy [7-8], (3) extra-curricular learning [9], and (4) social role identity theory [10-11].

(1) Valence, Instrumentality, Expectancy theory (VIE) [6] was used in several studies as a framework for understanding undergraduate students' motivation to participate in engineering outreach. This theory proposes that motivation arises from the interaction among elements of valence, or value of an activity, instrumentality, or the connection between an activity and the individual's goals, and expectancy, or the individual's perception that the activity can be successfully performed. Switzer and Benson [12] used VIE theory to examine changes in undergraduate engineering students' motivation as a result of participating in a three-week period of outreach. The premise of the study was that motivation would be impacted by outreach, and that motivation is also linked to remaining in an undergraduate engineering program. Although they did not find statistically significant changes, they noted positive shifts in students' responses to questions about value, instrumentality and expectancy of their engineering studies. Atwood & Fry [13] used the VIE framework to guide the development of open-ended prompts given to undergraduate engineering students after they had completed an outreach event. Using descriptive statistics and thematic analyses, the authors reported gender differences in how men and women viewed the outreach activity. Whereas valence was highly represented in men's responses, expectancy was a more prominent theme for women. Thematic differences were also apparent in the instrumentality of the activity, with women more likely to record goals of exciting students about engineering and men more likely to articulate goals of teaching content.

Bigelow [14] also used a VIE-informed reflection paper to investigate undergraduate engineering students' motivation towards outreach after participating in a biomedical engineering course in which an outreach activity was included. Using an inductive coding process, Bigelow identified 12 themes within the reflections, but these focused on lessons learned rather than valence, instrumentality, and expectancy specifically. Themes pertaining to shifts in undergraduates' assumptions or expectations included their recognition of the importance of hands-on learning, their surprise at how engaged the K-12 students were, and their discovery that young students did not know what engineering was. In addition, the undergraduates seemed divided on "whose job" it is to increase awareness of engineering as a career field, suggesting that they began to consider the broader societal issue of how to increase participation in engineering.

(2) Self-efficacy, defined as one's perception of one's own capability to successfully complete a task [7-8] was used as a guiding framework for assessing impact on ambassadors in a study by Anagnos, Lyman-Holt, Marin-Artieda and Momsen [15]. The study was grounded in the premise that ambassadors would benefit from self-efficacy for outreach and its associated components, including engineering knowledge and professional communication skills. Most of the 51 ambassadors responded that they perceived gains in skills to motivate others, resolve interpersonal conflicts, adjust when things were not going to plan, manage time, engage in teamwork, explain technical concepts, and speak in front of an audience. Ambassadors' confidence in their abilities was also high as a result of participating in outreach. Longer time in the ambassador program and more senior roles were associated with high rates of student agreement that they had experienced changes in confidence in a number of areas, including confidence to effect positive change through leadership, confidence to succeed in engineering, confidence to speak in front of others, and plans to attend graduate school.

Greene, Zhan, Anthony, Post & Parkhurst [16] used self-efficacy to consider the impact of outreach on teachers and undergraduate engineering students. In addition to interviews and field notes, the researchers administered the *Teachers' Sense of Self-Efficacy Scale* to teachers and undergraduate engineering students before and after they had implemented an outreach activity for middle school students. They found statistically significant gains in self-efficacy to engage students in outreach, which included being able to motivate students and help them value learning about engineering.

(3) The benefits of extra-curricular learning for undergraduate engineering students participating in outreach were explore in by Yowell, Zarske, Knight, and Sullivan [8]. Yowell et al. drew from prior work by Astin & Sax [9], who found that students who participated in volunteer extra-curricular activities, including outreach, reported an increased sense of civic responsibility and life skills. In addition, Yowell et al hypothesized that women might benefit more than men from engaging in service activities due to the provision of real-world connections and pro-social aims of the application of technical content. The researchers surveyed over 100 current and former undergraduate engineering peer mentors who had led after school engineering and STEM clubs in local elementary schools and asked about perceived impacts on professional and career skills including oral communication skills, fundamental engineering skills, future career plans, satisfaction with engineering studies, and undergraduate course selections. There were two areas where responses were nearly unanimous: most (85%) of the undergraduates currently in the leader role agreed that participation had impacted their oral communication skills, and 75% agreed that it had impacted their satisfaction with their engineering studies.

(4) Recently, researchers have begun to examine the impact of participating in outreach through the lens of identity formation and change, using frameworks based in social identity theory (SIT; [10]) and role identity theory [11]. Ross, Fletcher, Thamotharan & Garcia [17] examined the impact of a mentorship model of outreach by asking undergraduates to reflect on their self-perceptions. They drew from Godwin, Potvin, Hazari & Lock [18], who disaggregated the components of an engineering identity into performance/ competence, defined as a person's perception of their own competence in a field; interest, defined as perceived interest; and, recognition, defined as the degree to which the person perceives that others define or recognize them in a particular role. The researchers examined the impact of outreach on the ways that participants might talk about engineering, might act in or otherwise participate in engineering, might describe themselves in relation to engineering and how they might relate to others in the community in relation to engineering. A combination of inductive and deductive coding revealed that all but one of the respondents saw themselves as a "math, science, computer science, or engineering person." They expressed an identification with their respective STEM field and that participating in outreach had increased their awareness that others saw them as a "STEM" person and that acting in this role could bring altruistic gains in terms of inspiring others to follow a STEM career.

Other research used the Dynamic Systems Model of Role Identity [11] to examine the impact of engineering ambassador participation on undergraduates' developing sense of identity. The researchers propose that although students may possess multiple social roles, the role of ambassador can impact other roles such as young professional or beginning engineer. In several multiple case studies, Garner and colleagues [4, 19] interviewed newly trained and experienced engineering ambassadors, and revealed alignments between the students' personal histories and interests with engineering and the goals of the outreach program in which they were involved. Students' existing values and beliefs were found to align with the solution messages in the National Academy of Engineering *Changing the Conversation* report. Outreach training, mentorship and coordination activities allowed students to incorporate and practice new skills in technical communication and leadership in their roles as an ambassador and student leader, with several students recounting that such experiences also benefit their academic performance.

Research Question 3. What themes emerge from studies' findings about the impact of outreach on undergraduates?

An inductive, thematic analysis of the studies' main findings suggests two main clusters of impact on undergraduate engineering students. The first cluster can be defined as perceived changes in students' technical skills and career preparation, and the second cluster reflects impacts on students' identities and motivation.

Technical skills and career preparation. The majority (65%) of studies reported impacts on the undergraduate students' communication and/or presentation skills. Some studies also reported impacts on students' perceptions of their teamwork and organizational skills, time management skills, and their ability to present technical information to non-technical audiences. None of the studies we examined collected data pertaining to students' ordinary academic and coursework experiences. Therefore, the degree to which these skills actually transfer for the benefit of course achievement remains unknown.

Identities and motivation. A smaller subgroup (35%) of studies reported impacts of outreach participation on undergraduate students' motivation and identity. In regard to

motivational constructs, outreach participation was found to influence students' interest in continuing to engage in outreach efforts in the future, and was associated with increased satisfaction with engineering as a degree. Outreach participation was also associated with undergraduate agreement with the statement that they perceive themselves as a "STEM" person, which suggests that outreach can be linked, although not causally, to the development of a personal identification with the subject area. Intersectionality was noted in some studies in regard to gender, race, and demographic identities. Some studies reported that outreach led students to recognize the need and value of working with particular groups of underserved students, while others highlighted the ways in which students engaged in outreach might be motivated to do so due to personal affinities with underserved groups.

Discussion

This Work in Progress paper reports on the preliminary findings of a systematic review of studies investigating the impact of outreach participation on undergraduate engineering students. Our review indicates that outreach impacts students' technical and career preparation skills, specifically in the areas of communication and leadership, by providing explicit training and specific opportunities to convey engineering concepts to non-technical audiences. Outreach participation also has motivational and identity-related impacts on students by enabling them to explore new engineering-related roles in professional contexts and leverage their existing beliefs in pro-social applications of the field. Participation as an outreach mentor was linked to improved retention in the engineering degree and high levels of satisfaction with the choice to undertake an engineering degree.

Despite these promising findings, our review reveals areas where further research is needed. The research designs used to examine the impact of conducting outreach typically focused on evaluating the outcome for a single cohort of undergraduates, or changes in the knowledge and skills of undergraduates. This means that it is not possible to state the relative benefit or impact compared to students who do not participate in outreach.

Some studies described a professional development model used to develop the students' outreach skills, while others did not. Definitions of training also differed from one outreach model to another; student outreach preparation varied from participation in a course in which an outreach design assignment was included to required coursework in technical communication and weekly meetings to strengthen students' skills. Because very few studies connected specific aspects of professional development to particular outcomes, and none of the studies compared professional development models to one another, the question of which models of professional development might be optimal for which students in which contexts remains open.

A second area in which an empirical and methodological need emerged was in the measures or indicators of impact on the undergraduate students. Studies often included a researcher- or evaluator-designed survey or interview protocol. Although this approach might allow the investigators to ask questions specific to particular outreach programs or experiences, it made it challenging to compare findings across programs. In future, the development and validation of a uniform instrument to measure the impact of conducting outreach would allow researchers to investigate the impact of various types of experiences of different degrees of involvement on particular skills, attitudes, and behaviors. Similarly, the research designs used to investigate the impact of outreach are often descriptive rather than causal in nature. More research is needed to examine the effect of outreach as an intervention for a broad range of

undergraduate students rather than a pre-selected, high ability or minority-only subset of students. Longitudinal quantitative or qualitative research might prove to be effective in revealing the medium- and long-term impacts on students' post-graduation outcomes.

Finally, this review uncovered a need for more systematic application of theories and frameworks that can help researchers and evaluators synthesize existing knowledge about outreach participation, as well as formulate and investigate new questions about the impact of engineering outreach on undergraduates. The studies included in the review used a variety of constructs and models to conceptualize the impact of conducting outreach. Many studies did not draw a clear line between theoretical constructs and the measurement of outreach impact. A more comprehensive picture might be gained from studies that integrate theories of student engagement, college student learning, motivation, and development, and identity formation, and apply them in such a way as to acknowledge the intersectionality between various forms of social and personal identity and the experience of conducting engineering outreach. Next steps for our research group include a more detailed synthesis of these frameworks and the development and validation of a measure that can be used across different outreach programs.

Conclusion

The current body of literature suggests the presence of common impacts on undergraduate engineering students who participate in outreach. Communication and technical skills were frequently included as an area of improvement, along with motivational and identity-related constructs such as identification with engineering and self-efficacy for professional behaviors. Although research and evaluation of engineering outreach has increased over the past 20 years, further efforts must more clearly theorize, assess, and compare the impact of various types and intensities of outreach participation.

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Table 1a. Critical Features of Studies Examining Impact Pre- and Post-Outreach

Authors and Citation Number	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[20] Thole, Zappe, Marshall, Alley & Engel (2013)	Pennsylvania State University	Engineering Ambassadors Network (EAN)	Three characteristics of EA program: 1. Communication training workshop; 2. Outreach performed in middle and high schools; 3. Academic coursework to develop professional skills.	Outreach provides a professional development vehicle for engineering undergraduates.	Impact of training; process of scaling the network.	Pre- and post-training workshop surveys of 22 undergraduate ambassadors.	Statistically significant differences from pre- to posttest in: creating content that will engage audiences; establishing credibility with the audiences; knowing what details to include and what to leave out; selecting an appropriate slide design; delivering content in front of a large group; holding audiences' attention for 15-20 minutes.
[16] Greene, Zhan, Anthony, Post & Parkhurst (2014)	Ohio State University	Translating Engineering Research to K8 Students (TEK8)	Undergraduate engineering students matched with faculty members to conduct a summer project where they develop activities for middle school classrooms; also contribute to 6 weeks of afterschool programming.	Programming can impact undergraduates' self-efficacy for generating interest in engineering among middle school students.	Investigate changes in self-efficacy, reciprocal learning between undergraduates and teachers.	Mixed methods evaluation study: interviews, observations, and a pre- and post-self-efficacy survey. Within and cross-case analysis and discourse analysis.	Statistically significant gain in self-efficacy. Undergraduates were already confident in content knowledge but gained in self-efficacy for presentation skills and leading design challenges.
[21] DeWaters, Powers & Graham (2006)	Clarkson University	Partners In Engineering (PIE)	Teams of female engineering students work with teacher to provide a 3 week long engineering problem solving class to 8th grade students.	Importance of provision of leadership opportunities for female undergraduates.	None articulated.	Pre and post-program survey, focus group and problem solving quiz.	Undergraduates with weak initial problem solving skills reported perceived benefits from problem solving aspect of program. Those with strong problem solving skills reported strong satisfaction. Perceived improvement in public speaking and teamwork and a rewarding experience.
[22] Carberry, Portsmore & Rogers (2007)	Tufts University	STOMP: Student Teacher Outreach Mentorship Program	Undergraduates work with teachers to conduct outreach.	Outreach can improve undergraduates' civic responsibility, teamwork and communication skills, assist in the identification of career paths, and prepare them for the demands of their future workplaces.	Impact on various stakeholders.	Experimental design: 12 outreach undergraduates, 7 in introductory engineering course. Pre- and post-test of knowledge.	No statistically significant differences. Authors report experimental group gained in integration of engineering knowledge into K-12 content and comparison group gained in being able to determine relevant features for a design project.

Table 1a (continued). Critical Features of Studies Examining Impact Pre- and Post-Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[23] Jordan-Bloch & Cohen (2018)	Stanford University	Seeds of Change	Train the trainer model. Leader training meetings where female undergraduates learn curriculum and how to teach/lead others.	Curriculum has a theory of action including mindsets, persistence, mentoring and leadership.	Investigate lessons learned from the program.	Reflections from leader; pre and post interviews and surveys for participants.	Self-reported increase in content knowledge. Undergraduates' attention was drawn to leadership as an area of growth.
[24] Atwood, Patten & Pruitt (2010)	University of California, Berkeley	Structural aspects of biomaterials (course) Body By Design Outreach Activity	Undergraduates develop an outreach activity for elementary students at a museum. Undergraduates examined Bloom's taxonomy, communication skills, and teamwork.	Increasing perceived relevance of engineering to society may help retain female undergraduates. Female students' communication skill strengths may be developed and used through outreach.	Investigate impact of incorporating design and outreach into undergraduate course.	Pre- and post-course survey administered to 48 undergraduate students. Analyses separated impact by gender.	Women ranked outreach activity as being more useful than men. Women indicated higher self-confidence than men at the beginning and end of the course. Men had higher self-confidence in evaluating written and analytical work of themselves and others. Both gained in overall confidence from pre- to post survey.
[14] Bigelow (2010)	University of Dayton	Biomedical engineering (course) Prosthetic Hand Outreach Activity	Service learning activity within course. Undergraduates teach K-12 students about biomedical research. Students choose how they want to conduct the outreach.	Outreach motivation can be investigated through constructs of Valence, Instrumentality, and Expectancy.	Investigate impact of conducting outreach.	Pre and post-semester survey about biomedical engineering outreach. Post-outreach reflections.	Self-reported changes in their perceptions of the need for engineering outreach. Lessons learned in four areas: setting up and conducting an outreach activity; learning to work with young adults; awareness of engineering; importance, and role of diversity.
[25] Sullivan & Zarske (2005)	University of Colorado, Boulder	K-12 Engineering Outreach Corps	Engineering used as a vehicle for teaching science and math. Undergraduates take a class to prepare them to lead outreach.	Undergraduates gain knowledge not included in coursework. Retention of women and students of color can improve using an authentic curriculum that includes outreach.	None articulated.	Pre- and post-semester surveys, observations, focus group.	Self-reported increases in integrating engineering fields and integrating curriculum into K-12 classrooms, develop K-12 engineering curriculum, and work with children. Decreases in confidence to work with K-12 principals and work with special needs children.

Table 1a (continued). Critical Features of Studies Examining Impact Pre- and Post-Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[12] Switzer & Benson (2007)	Clemson University	Engineering Fundamentals (Class) 3 week design project	Undergraduates create active learning tools for middle and high school students.	Valence Instrumentality Expectancy theory (Vroom, 1964).	None articulated.	Survey of 160 undergraduates before and after design project.	Trends but no statistically significant changes in value of behavior, value of goal, instrumentality, or expectancy.
[26] Atwood & Frey (2013)	Elizabethtown College	Strength of materials (Course)	Outreach performed as part of coursework.	Motivation to perform outreach involves: Valence (value), Instrumentality (connection between activity and progress towards goals) and Expectancy (ability and skills to perform outreach successfully). Outreach meets ABET criteria a, c, f, g, i.	Investigate gendered impact of performing outreach.	Open-ended reflection after outreach: What happened? What does it mean? What will you do? Pre-activity survey on confidence in technical communication.	Value of outreach differed for men and women: male students emphasized challenges associated with outreach and female students emphasized communication skills and value of working with children. Both men and women were aware of gender inequity in engineering.

Table 1b. Critical Features of Studies Examining Post-Hoc Impact of Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[3] Alley, Haas, Garner & Thole (2015)	Various	Engineering Ambassadors Network (EAN)	Three characteristics of EA program: 1. Communication training through the workshop; 2. Outreach performed in middle and high schools; 3. Ambassadors learn professional skills through academic programs and courses.	Communication training including online training will enhance undergraduate professional development and increase Network impact.	Assess impact of training and identify critical features of individual chapter success.	Post-workshop Likert scale survey of 170 ambassadors	97% of survey respondents responded that the training exceeded their expectations; 75% indicated they could create content that would engage an outreach audience; 74% create slides that would help the audience understand information; 72% select appropriate slide design; 68% provide a helpful critique of a peer's presentation; 66% know what to include and what to exclude in an outreach presentation; 61% integrate Changing the Conversation messages.
[27] Haas, Alley, Garner & Thole (2016)	Various	Engineering Ambassadors Network (EAN)	Engineering Ambassadors Network training scaled to other new and existing chapters.	Communication skills are necessary for undergraduate engineering students.	None articulated.	Mixed methods study: interviews with ambassadors and post-training survey of 170 ambassadors.	Undergraduate ambassadors expressed a personal commitment to maintaining involvement in outreach at their institution. Perceived increase in public speaking confidence skills and ability to create an effective outreach presentation. 95% of respondents thought the training was a good networking opportunity. 80% indicated being able to communicate messages from Changing the Conversation.
[28] Shabhazi, Lehnes, Jacobs & Mancuso (2016)	Manhattan College	Engineering Ambassadors	Variation on EAN; collaboration between School of Education and Health and local high school.	Outreach can encourage enrollment in undergraduate engineering education minor; improve engineering students' presentation skills.	None articulated.	Survey of 89 undergraduates.	Undergraduates could describe the lesson they had developed and could rate peer presentations; reported an improved understanding of learning styles.

Table 1b (continued). Critical Features of Studies Examining Post-Hoc Impact of Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[15] Anagnos, Lyman-Holt, Marin-Artieda & Momsen (2014)	Oregon State University Howard University	Engineering Ambassadors	Outreach to campus visitors, lead tours, meet with engineering professionals who visit campus. Training for ambassadors includes 2 day workshop, and running a 4 day student orientation.	Development of professional skills is a priority; STEM and engineering self-efficacy can be developed through outreach; self-efficacy promotes persistence in STEM.	Investigate impact of engineering ambassador program on undergraduate student development.	A previously validated Likert scale survey was administered to 51 current and former ambassadors at two programs.	Ambassadors had multiple goals for participation, including making a difference in their community, building a connection with their engineering program, building their resume, and having fun. 85% of ambassadors perceived gains in confidence to speak in front of others; 80% indicated improved confidence to succeed in engineering; 100% perceived positive effect on their leadership skills.
[29] Talbot (2013)	Pennsylvania State University	Engineering Ambassadors Network (EAN)	Credit bearing communication training; focus on Changing the Conversation messages; teams perform outreach presentations and hands-on activities; leadership training through required reading and meetings.	Employers desire engineering graduates with strong communication skills and outreach can function as a context for the professional development of these skills.	None articulated.	Surveys of current ambassadors on leadership and communication training; post-training survey of 45 ambassadors.	94% of respondents developed increased confidence in presenting engineering content; 83% reported being more motivated to learn course content; 72% agreed outreach presentation development allowed them to transfer information outside of their courses. Post-training surveys revealed gains in confidence to engage audiences, establish credibility with audiences, know what to include and exclude, how to select an appropriate slide design, and deliver content in front of a large group, and hold audience attention.
[30] Caldwell, McCoy, Albers, Smith & Parry (2007)	North Carolina State University	RAMP: Recognizing Accelerate Math Potential in Underrepresented People	Undergraduate fellows work 10 to 15 hours per week. Weekly meetings, bi-monthly dinners, seminars.	Participation may impact undergraduate and graduate fellows' career plans.	Impact on undergraduate fellows' communication skills, teaching skills, STEM content knowledge.	Survey of 42 current and 8 former fellows.	All respondents indicated participation was a rewarding experience; 86% recommended participation. Perceived increases in communication skills, career preparation, content knowledge.

Table 1b (continued). Critical Features of Studies Examining Post-Hoc Impact of Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[31] Bates, Krapcho & Orantes (2014)	University of Utah	Ambassador Program	Undergraduates are trained to interact with students of varying ability, develop outreach activities and presentations; students participate in community and campus events, including visits to high school classes.	Undergraduate student retention can be improved through community building. Communities of ambassadors can promote practical competence, personal and social development, and deeper engagement.	Investigate ambassadors' experiences.	Survey of 37 ambassadors: reasons for participation, reasons for enrolling in engineering, post-graduation plans.	Ambassadors reported a much reduced consideration of switching major; improved presentation skills; improved social connections; improved sense of accomplishment.
[7] Yowell Zarske, Knight & Sullivan (2013)	University of Colorado, Boulder	TEAMS: Tomorrow's Engineers...creAte, Imagine, Succeed	Weekly TEAMS clubs led by undergraduate students in elementary schools. Boxed activities are performed.	Value of extracurricular volunteer activities on undergraduates includes improved communication, content knowledge, and teaching skills. Impact particularly for women.	Investigate leaders' experiences.	Survey of a total of 34 undergraduates (gathered over a 3 year period).	Respondents indicated impact on oral communication skills and satisfaction with engineering studies. Lower levels of impact on fundamental engineering skills and future career plans. Realization of challenge of communicating to non-technical audiences. Outreach as a possibility for action in future jobs.
[32] Haas, McElholm, Renfro, Herkenham, Marshall & Alley (2013)	Worcester Polytechnic University	Engineering Ambassadors Network (EAN)	Implementation of Changing the Conversation messages; performing outreach to middle and high school students; focus on ambassador professional development through academic programs.	Bringing the outreach programs of multiple Colleges of Engineering together can promote sharing of resources and information, encourage mission development, and develop community for ambassadors.	None articulated.	Mixed methods study: demographics of ambassadors; visit logs; surveys of 20 ambassadors from one institution.	Survey findings revealed 94% developed confidence presenting engineering content; 83% perceived participation helped them develop self-direction and responsibility; 60% indicated a better understanding of engineering; 49% indicated an increased interest in engineering content.

Table 1b (continued). Critical Features of Studies Examining Post-Hoc Impact of Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[33] Scherrer (2013)	Southern Polytechnic State University	Outreach funded under NSF BRIGE grant	Undergraduates visit high schools to give presentations about how engineers "do good" in the world.	None articulated.	How participation affects undergraduates' interest in remaining in program or career; likelihood of graduate school; interest in K-12 STEM.	Survey of 11 undergraduates.	Undergraduates reported personal benefit of communication skills that transferred beyond outreach. Personal satisfaction in helping others. Meaningful outcome of opportunity to shape others' futures. Outreach participation did not impact degree completion or graduate school plans.
[34] Ciston, Wordsall & Swenson (2010)	Northwestern University	STEP: Summer Technology & Engineering Program	Undergraduates conduct 3 full days of outreach to 7th and 8th grade girls. Outreach includes classroom activities, field trip, design project and research lab tour.	Undergraduate female student motivation to participate.	None articulated.	Survey of 10 undergraduate and graduate facilitators who rated various sources of motivation.	Undergraduates felt it was important for junior high school girls to see women in engineering and to increase women's participation in engineering. Money and professor encouragement were the lowest rated source of participants' motivation.
[35] Salzman & Strobel (2011)	Purdue University	Purdue FIRST Programs (PFP)	FIRST Robotics competition where 12 university students mentor 18 high school students.	Service learning and mentoring bring cognitive and social benefits to the undergraduates.	Investigate motivation of undergraduates to mentor high school students and what mentors gain from being mentors.	Survey of 10 students with 1-6 years of involvement in program. Open and deductive coding.	Motivation to participate influenced by prior FIRST Robotics participation. Undergraduates perceived gains in teaching, technical, communication, time management, and leadership skills. Undergraduates perceived development of technical and process skills.
[36] Bowling, Doyle, Taylor & Antes, (2015)	Northern Kentucky University	STEM Ambassadors.	Undergraduates act as peer mentors, conduct outreach and attend recruitment events. Training includes facilitating an orientation workshop, assignments, mentorship, leadership, and coaching training.	Academic and social integration and perceived belonging to a disciplinary community promotes retention of undergraduate students.	Investigate retention effects of ambassadorship.	Open ended question survey of 10 ambassadors; statements from mentees; retention data.	STEM ambassadors reported learning lessons of trusting team members, delegating, being aware of others' perspectives, realizing it is acceptable to be vulnerable, maintaining a focus on 'big picture' issues, and recognizing and honoring commitments. Retention of STEM students who interacted with ambassadors was higher than those who had not.

Table 1b (continued). Critical Features of Studies Examining Post-Hoc Impact of Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[37] Epstein, Mire, Ramsey, Gareis, Davidson, Jones, Slosberg & Bras (2010)	Massachusetts Institute of Technology	Terrascope Youth Radio (TYR)	Engineering and science undergraduates act as mentors for a 6 week summer program where they with teenagers to produce radio and audio programming on environmental topics.	Generational links between older and younger students.	Investigate successes, challenges, rewards of being a mentor.	Survey of open-ended questions responded to by 4 out of 8 mentors.	Undergraduates reported learning specific mentoring skills including giving guidance and engaging in critical thinking. One respondent indicated improving these skills herself.
[19] Garner, Alley, Haas, Sontgerath & Kaplan (2017)	Various	Engineering Ambassadors Network (EAN)	Outreach to middle and high school students; communication training for ambassadors.	Outreach can be a form of professional development and can impact the ambassadors' self-perceptions, purpose and goals, beliefs, and possibilities for action.	Investigate purpose of the hands-on activity for students in an ambassador role; process of developing hands-on activity.	Case study with embedded units. Interviews with 8 ambassadors after a week-long training.	Undergraduates perceive that hands-on activities serve a learning purpose and engage students in what it means to be an engineer. Ambassadors had to consider the integration of content, pedagogy, and technical constraints.
[38] Garner, Alley, Haas & Kaplan (2016)	Various	Engineering Ambassadors Network (EAN)	Three characteristics of EA program: 1. Communication training through the workshop; 2. Outreach performed in middle and high schools; 3. Ambassadors learn professional skills through academic programs and courses.	Professional identity development occurs as a by-product of participating as an engineering ambassador and performing outreach; particular benefit if the ambassador is from an underrepresented group. Use of Dynamic Systems Model of Role Identity as a theoretical framework.	How identities inform motivation to become an ambassador; how training crystallizes identity as an ambassador for the field of engineering; features of the workshop that promote identity formation.	Case study with embedded units. Interviews with purposeful sample of 6 undergraduate ambassadors.	Ambassadors' beliefs echo the problems and solutions included in Changing the Conversation; ambassadors' professional goals are broadly aligned with Changing the Conversation; Ambassadors' own professional development was not a prominent motivation to participate in outreach; action possibilities for outreach were clear as a result of the workshop training; ambassadors' choice of outreach presentations reflected existing interests.

Table 1b (continued). Critical Features of Studies Examining Post-Hoc Impact of Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[4] Garner, Haas, Alley & Kaplan (2018)	Various	Engineering Ambassadors Network (EAN)	Three characteristics of EA program: 1. Communication training through the workshop; 2. Outreach performed in middle and high schools; 3. Ambassadors learn professional skills through academic programs and courses.	Training for participation in outreach provides a context for undergraduate identity development; theoretical framework of Dynamic Systems Model of Role Identity used to understand identity development processes and outcomes.	How do individuals' existing identities motivate them to become ambassadors? How did the training workshop shape undergraduates' understanding of the ambassador role? Which features of the workshop promote identity development?	Qualitative case study with 6 embedded units. Interviews were coded using the DSMRI theoretical framework; cases were synthesized; cross-case analysis.	Incoming role identities of the ambassadors were aligned with the messages of Changing the Conversation and the mission of the EAN organization; the training workshop allowed sharing of existing engineering knowledge and skills and ways to hone and communicate knowledge; presentation skills training and the social context emerged as important workshop features.
[39] McFalls, Grimes, Mohammadi-Aragh, Sullivan & Warncok (2015)	Mississippi State University	None provided.	Undergraduates participate in residential summer program aiming to recruit students and inform them about engineering. Outreach includes research, tours.	None articulated.	Investigate how the experiences for the undergraduates can be improved.	Autoethnographic study with open ended prompts about program goals and their experiences completed by 2 participants.	Undergraduates had an existing engineering identity upon beginning participation. Respondents reported learning along with students. Increased appreciation for interdisciplinary nature of engineering, increased organizational and planning skills.

Table 1b (continued). Critical Features of Studies Examining Post-Hoc Impact of Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[40] Mustafa & Freese (2018)	California State University, Chico	Imagineer Day	Undergraduates lead an annual one-day event with hands-on lab experience demonstration of basic engineering concepts.	Society for Women Engineer group of female undergraduates providing outreach to K-8th grade girls.	Evaluate the impact of participation on female undergraduates.	Survey of participating undergraduates.	Undergraduates perceived impact on time management, public speaking, teamwork, leadership and communication skills. Respondents did not report gains in understanding of engineering but grew interest in promoting STEM.
[41] Olds, Patel, Yalvac, Kanter & Goel (2004)	Northwestern University	Project Prosthesis: Helping Hands (PPHH)	Students develop a 600 minute module and test it in a classroom.	Integration of learning theory with societal benefit of engineering.	Investigate gains in undergraduates' understanding.	Survey with open-ended questions.	All respondents indicated interaction with faculty and students was one reason for participation. 90% perceived a gain in understanding and utilization of engineering design processes. 90% reported an increase in interest in teaching and curriculum development. 80% perceived an increase in communication skills.
[42] Olds, Kanter, Knudson & Mehta (2003)	Northwestern University	Biomedical Engineering Outreach	An 8-12 class period module developed by undergraduates and faculty members, designed for middle school students. Undergraduates attend classes and discuss homework, guide activities, manage structure and time, observe, take notes.	None articulated.	Investigate change in undergraduates' understanding of teaching and learning process.	Survey with open-ended questions.	Undergraduates reflected on content and learning outcomes. Summary of findings indicated gains in leadership, management and communication skills.

Table 1b (continued). Critical Features of Studies Examining Post-Hoc Impact of Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[43] Rivas & Olmsted (2013)	Iridescent	Be a Scientist! (BAS)	Undergraduates design and teach family science workshops to groups of underrepresented elementary school children and families in museums and schools.	Engineering students can act as instructors.	Impact of the project, including on undergraduates.	Surveys, interviews, logs, observations, and concept maps.	Undergraduates commented that they learned practical skills, public speaking and collaborative skills, and the ability to simplify and break down concepts.
[44] Albers, Smith, Caldwell, McCoy, Bottomly, & Parry (2008)	North Carolina State University	RAMP: Recognizing Accelerate Math Potential in Underrepresented People	Undergraduate and graduate students conduct hands on activity based outreach to math and energy clubs in local inner city elementary schools.	Participation may impact undergraduate and graduate fellows' career plans.	Impact on various stakeholder groups.	Surveys of undergraduate and graduate fellows in which respondents indicated agreement with various statements.	Fellows indicated positive impacts on their personal development, educational relationships, and STEM knowledge.
[17] Ross, Fletcher, Theamotharan & Garcia (2018)	Florida International University	Verizon Innovative Learning (VIL) Program	Undergraduates hosting middle school underrepresented male students at a summer camp. Engineering habits of mind, design theory, computing, 3D printing. Two days of training for facilitators.	Social Identity Theory: performance/competence, interest, recognition of competence. Mentor relationships can be mutually beneficial, in part due to similarity between mentor and mentee.	Role of race and gender in student mentor relationships; implications of mentor relationships on STEM identity development of the student mentors.	Survey including open-ended questions. Inductive and deductive coding based on Social Identity theory Thematic coding for race, altruism, and gender.	Undergraduates entered program with a pre-existing STEM identity. Mentoring highlighted altruism and raised salience of identity, where identity was defined via performance/competence and interest.
[45] Frey & Atwood (2013)	Elizabethtown College	Strength of Materials (Class)	Service learning in which undergraduates create an outreach activity within coursework.	Literature derived need for engineers who can convey information and relate to younger students; need for diversity.	Investigate impact of participation on undergraduates' recognition of the need for outreach.	Open-ended individual reflection: What happened? What does it mean? What will you do?	77% of respondents were enthusiastic about continuing outreach after graduation. Undergraduates felt that instilling enthusiasm in younger students was rewarding.

Table 1b (continued). Critical Features of Studies Examining Post-Hoc Impact of Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[46] Jahan, Sukumaran, Head & Keil (2012)	Rowan University	Project AWE	Undergraduates and faculty work together to provide a 2 day camp for middle school girls that includes lecture and lab activities, tours, and field trips.	Value of mentoring and potential reciprocal benefits.	None articulated.	Undergraduates provided quotes to supplement evaluation of program.	Mentors perceived the experience to be educational; they had to strike a balance between being an authority figure and a friend. Perceived increase in personal responsibility.
[47] Brown & Thomas (2011)	Virginia Polytechnic Institute and State University	National Society of Black Engineers Technical Outreach Community Help (NSBE TORCH)	Service learning that includes fundraising and presentations to K-12 audiences that visit campus.	Participation in service learning and outreach can impact motivation	Investigate the impact of participation on college students.	Surveys including demographic information, ranking statements, and open-ended questions of undergraduate students.	Thematic statements referred to students valuing the technical aspects of their education, the importance of volunteering, a commitment to continuing with outreach throughout their career, and appreciating applications of technical skills to other areas of life.
[48] Greene, Post & Abrams (2015)	Ohio State University	Hometown Ambassadors (HA)	Early career engineers perform outreach to high school students without explicitly recruiting to the university.	Value of upperclass undergraduates providing near peer mentorship and acting as role models to high school students.	None articulated.	Survey of alumni.	Alumni reported changes in understanding about fields they were unaware of previously.
[49] Chakravartula, Ando, Li, Gupta & Pruitt (2006)	University of California, Berkeley	Structural Aspects of Biomaterials (Class)	Undergraduates develop outreach during class time. Outreach delivered to 4^{th} and 5^{th} grade students at field trip to Lawrence Hall of Science.	Undergraduates' deep learning of content results from teaching it; outreach teaches undergraduates about the interdisciplinary nature of engineering and improves teamwork skills.	None articulated.	Observations and self-evaluations; written assignments; final project product.	Undergraduates reported learning about teaching and simplifying topics; desire to help female students become interested in biomedical engineering.

Table 1b (continued). Critical Features of Studies Examining Post-Hoc Impact of Outreach

Authors	Institution	Program	Outreach Model	Premise or Theory of Action	Purpose or Research Questions	Methods	Impact on Undergraduates Conducting Outreach
[50] Pomales-Garcia, Suarez, Padovani & Alvarez (2018)	University of Puerto Rico	Materials Science and Engineering (MSE) Clubs	Year round Material Science and Engineering clubs; summer program for high school students and teachers. Undergraduates received training on nanotechnology demonstrations and presented them to low income middle and high school students.	None articulated.	Program evaluation results reported.	Participation log.	Anecdotal quotes referred to becoming a better mentor, communicating difficult topics, giving back to society, and helping to discover engineering opportunities.
[51] Steele & Waggenspack (2018)	Louisiana State University	STEP: STEM Talent Expansion Program	Upper level peer mentor undergraduates assist with summer bridge camp.	None articulated.	None articulated.	Retention rates.	Peer mentors were more likely to be retained than undergraduate students who had not participated as a mentor.

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