Validation of the Ambassador Questionnaire for Undergraduate Students Conducting Engineering Outreach

Melissa G. Kuhn
Old Dominion University, mgkuhn@odu.edu

Shanan Chappell Moots
Old Dominion University, schappel@odu.edu

Joanna K. Garner
Old Dominion University, jkgarner@odu.edu

Original Publication Citation

Kuhn, M. G., Moots, S. C., & Garner, J. K. (2022). Validation of the Ambassador Questionnaire for undergraduate students conducting engineering outreach. *International Journal of Engineering Education*, *38*(5), 1223-1242.

International Journal of Engineering Education Vol. 38, No. 5(A), pp. 1223–1242, 2022
Printed in Great Britain
0949-149X/91 $3.00+0.00

Validation of the Ambassador Questionnaire for Undergraduate Students Conducting Engineering Outreach*

MELISSA G. KUHN**, SHANAN CHAPPELL MOOTS and JOANNA K. GARNER
The Center for Educational Partnerships, Old Dominion University, 4111 Monarch Way, Suite 406, Norfolk, Virginia, United States of America, 23508, USA. E-mail: mgkuhn@odu.edu

Although K-12 engineering outreach commonly involves college students, the young professionals who act as ambassadors for their field are less likely to be studied than the students they serve. Yet, outreach activities may offer opportunities for undergraduate students to develop aspects of their professional selves. As there is currently no comprehensive measure that allows researchers, program evaluators, and outreach advisors to examine ambassadors' professional development and growth, this study sought to develop and validate an Ambassador Questionnaire (AQ). The multi-step process included the selection and adaptation of items from extant measures of engineering students' motivation, beliefs, professional skills, and perceptions of ambassador training. After an expert panel evaluated the initial group of items, the 57-item AQ was completed by a diverse group of 350 undergraduate engineering students engaged in ambassadorship. Exploratory and confirmatory factor analyses were used to examine construct validity, and internal consistency reliability analyses followed. The findings indicated a five-factor model that accounted for 53% of the variance and demonstrated strong internal consistency reliability. Potential uses for the measure are discussed.

Keywords: K-12 STEM outreach; undergraduate students; engineering ambassadors; program evaluation; engineering identity

1. Introduction

To recruit and retain a more diverse student body into science, technology, engineering, and mathematics (STEM) fields, many colleges and universities have formed groups that use undergraduates to conduct K-12 education outreach [1, 2]. Each year, thousands of undergraduate engineering students act as "ambassadors" and serve K-12 audiences through classroom demonstrations and presentations about engineering applications, career opportunities, and the importance of diversity in STEM. Though researchers have examined the effect of outreach on the STEM-related attitudes, career awareness, and knowledge of engineering fields among pre-college students [3–7], less is known about the potential impact of ambassadorship on the undergraduates. Yet, training, and sustained immersion in outreach activities that involve conveying information about engineering and the utility and value of engineers may affect students' perceptions of themselves as emerging professionals and the knowledge they possess as they prepare to enter the workforce.

In this study, we developed a questionnaire designed to measure the self-perceptions and beliefs of undergraduate engineering students who are involved in co-curricular programs that train and deploy them in K-12 engineering outreach. The *Ambassador Questionnaire* is intended for use in engineering outreach research, program evaluation, and program management. It is aligned with literature on psychological attributes that contribute to the development of an engineering identity, persistence in a STEM degree program, and self-perceptions as an effective communicator about engineering. Specifically, the measure builds on qualitative studies of ambassadorship impact that have noted themes of engineering identity and career exploration, changes in leadership skills and confidence in public speaking, an articulated sense of purpose and belonging within the engineering field, an awareness and endorsement of pro-social applications of engineering, and feelings of membership in a diverse and supportive professional community [8–12]. Our aims are to provide a quantitative tool that is of practical use for large, diverse ambassador groups and move towards a coherent theoretical framework for the ambassador role and its potential to impact undergraduate engineering students' development.

1.1 Engineering Ambassadors in K-12 Outreach

The engineering outreach and ambassador movement reflects a variety of university affiliated programs that offer outreach visits to K-12 classrooms. Although many outreach groups operate independently, in the United States one group has come together to form the *Engineering Ambassadors Network* (EAN) [13]. The EAN includes outreach

** Corresponding author.

* Accepted 27 March 2022.

programs at approximately 30 universities and colleges that subscribe to a common mission and goals and use similar training and outreach methods to engage undergraduates for one or more years of their undergraduate career. EAN chapters develop relationships with their local middle and high schools and provide regular visits that supplement students' understanding and appreciation for topics in the curriculum, as well as improved awareness of engineering career opportunities and social impact. Visits often include a presentation and hands-on activity. Many chapters focus on visiting high-needs schools and/or schools in which a substantial proportion of the students are from historically underrepresented racial and ethnic groups in engineering[1]. An important goal is to inspire K-12 students to become more interested in and aware of possibilities associated with engineering and other STEM majors at the post-secondary level. Efforts often include specific messaging that is designed to invite participation by historically underrepresented groups in STEM fields, including females and racial-ethnic minorities [14]. Outreach presentations also commonly describe innovations that improve societal health, wellbeing, and sustainability, and may be delivered by undergraduate students who are members of one or more historically underrepresented groups in engineering The use of specific messaging strategies that use clear technical communication to teach innovative applications of engineering that benefit society is a defining characteristic of EAN presentations, as it facilitates the Network's twin goals of recruitment (through outreach) and retention (through ambassadorship activities) of a diverse undergraduate student body.

1.2 The Ambassador Role as a Context for Growth

Research on engineering outreach has mostly focused on changes in knowledge and attitudes among the recipients including K-12 students and teachers [7]. However, over the past decade studies have suggested that outreach might have mutual benefits, with some researchers proposing that it can serve as a vehicle for developing undergraduate students' professional sense of self in the role of ambassador for the field of engineering [10]. The context of ambassadorship may support growth, as both the outreach delivery and the student-run organization components of ambassadorship programs provide authentic opportunities that are not otherwise commonplace in engineering coursework. For example, undergraduate students can develop public speaking and organizational leadership skills by planning and executing classroom teaching. By engaging in peer mentoring of junior ambassadors and creating engaging talks and demonstrations about engineering, students gain the opportunity to explore different career avenues within the field. This supportive context can allow students to explore their beliefs and goals in ways that sustain their engineering career motivation. These experiences may be of particular benefit for female and underrepresented racial or ethnic groups as for some students the confidence gained from mentoring peers, leading school visits, and interacting as a young professional with teachers and students may help to mitigate the impact of other, marginalizing experiences [15].

The structure of some outreach programs is aligned with this recognition of the opportunity for growth. For example, although it reaches more than 200,000 K-12 students and teachers each year [13], the EAN explicitly includes undergraduate professional development in its mission statement. Students participating in EAN programs receive common training through regional and national workshops that emphasize the use of the prosocial messages about engineering contained in the National Academy of Engineering *Changing the Conversation* study, and the use of a research-based *assertion evidence* strategy for developing and delivering classroom presentations [9, 16]. During training, ambassadors collaborate in small teams of two or three to identify an engineering topic of contemporary significance and likely interest among middle and high school audiences. Trainees receive multiple opportunities to deliver a draft presentation and receive structured feedback from peers and mentors. They deliver their final presentation in a "showcase" style event. After this initial training, ambassadors meet regularly during the school year to prepare outreach activities and develop new presentations. To support this, ambassadors have access to online resources including tutorials on public speaking and sample classroom activities, and they receive guidance from a faculty advisor. The EAN encourages peer mentoring among ambassadors and manages an alumni group that serves as a networking and teaching resource for current ambassadors and chapter advisors. Chapters make deliberate efforts to recruit students from historically underrepresented groups including women, individuals of color, and first-generation college students [8] and maintain a goal of successful degree completion by all ambassadors. In many cases, ambassadors participate in their EA chapter for multiple years throughout their undergraduate career.

[1] Historically underrepresented racial and ethnic groups in science and engineering includes those who identify as Black, Hispanic/Latino, or American Indian/Alaska Native, per the 2017 National Science Foundation definition of underrepresented groups in science and engineering: https://www.nsf.gov/statistics/2017/nsf17310/digest/introduction/

Success in STEM at the baccalaureate level has been linked with the possession of several psychological attributes including positive self-definitions, self-beliefs, career motivations, and career intentions about engineering, and a sense of belonging within the field [17–19]. Statements aligned with these constructs are often articulated by EAN-trained ambassadors, who appear to benefit from both the professional development provided in the training and the outreach opportunities that follow in ways that support identity formation processes such as career and self-exploration. Alley and colleagues [9] found that EAN training was associated with increases in undergraduates' self-efficacy and perceptions of preparedness to design and deliver effective outreach presentations. In another study, Garner and colleagues [10] found that training combined with at least one year of outreach participation was associated with an emerging sense of identity in the role of ambassador. This included a cluster of positive self-perceptions in the roles of ambassador and future engineer, combined with pro-social beliefs about engineering that were closely aligned with *Changing the Conversation* messages, and perceptions of social support from others that promoted intentions to remain in the major. The authors noted that ambassadors also described how they gained confidence in professional skills by providing feedback to other students on their presentations and further developed their own career motivation by exploring their own interests as a source of inspiration for outreach topics. These findings are echoed by several studies involving non-EAN engineering outreach programs as well [20, 21]. However, the small-scale and mostly qualitative nature of outreach impact research highlights the opportunity to more systematically explore the potential impact of ambassadorship on undergraduate engineering students.

2. Candidate Constructs for the Ambassador Questionnaire

Engineering outreach program goals and ambassador role activities align with several clusters of constructs in the literature on engineering student development: academic and career confidence, domain and contextual beliefs about studying engineering, and professional communication skills.

2.1 Academic and Career Confidence

Self-efficacy is often used to describe confidence in one's abilities to successfully engage in a particular task [22]. It has been associated with undergraduate student degree completion and persistence in STEM fields, particularly for women and students of color [23–25]. A variety of academic and career self-efficacy measures exist, and several have been used to examine changes in self-efficacy over time for different subgroups of college students in engineering and related majors [19].

Academic self-efficacy could be impacted by co-curricular efforts that support the development of students from historically underrepresented groups who are studying engineering. For example, analyses of large data sets from the self-efficacy scales in the *Project to Assess Climate in Engineering* (PACE) [23] revealed gender differences in academic confidence, with women scoring significantly lower than men. However, in the validation study of the *Longitudinal Assessment of Engineering Self-efficacy* (LAESE) using respondents who were participants in co-curricular women in engineering programs, Marra and Bogue [25] reported stable trends in various aspects of women's self-efficacy including self-efficacy for engineering, coping with academic difficulties, and for their future careers. The inclusion of academic self-efficacy allows outreach researchers to consider hypotheses about programs as a source of navigational or cultural capital that can contribute to academic confidence and wellbeing [26].

2.2 Domain and Contextual beliefs about Studying Engineering

The alignment between the outreach mission of communicating prosocial messages about engineering and research on students' beliefs about engineering led us to consider motivation and belief related items. Motivated decisions to pursue an engineering major often reflect a combination of career and ontological (worldview) beliefs about engineering. Motivations can be plural and include an interest or passion for the subject matter, a desire to use the degree for career advancement, and the desire for a professional, well-paying job [27]. Students' personal beliefs about the value they ascribe to degree attainment and the application of engineering to problem solving are also important [28].

Some researchers have aligned students' engineering beliefs with internalized values that sustain motivated action [29, 30]. In this case, an alignment between beliefs and values about the importance or role of engineering in society or the need to recruit the next generation of engineers, might support sustained engagement in outreach. Indeed, engineering students who participate in service-related organizations often self-identify as attentive to social justice applications of engineering [9, 12, 31, 32] or feel increased intrinsic value in the field [33]. Relatedly, ambassador programs often strive to recruit females, first generation college students, and students of color, who are more likely to

articulate the importance of engineering as a benefit to society as a source of motivation for the field [27]. Students' beliefs, and how they may develop over time, are therefore of interest to those studying and managing outreach programs.

Students' beliefs about the social context in which they study engineering have also been found to be influential in predicting retention in engineering degree programs. From an outreach leadership perspective, students' ratings of the social climate in which they are studying may prove to be informative as it may enable the identification of groups of students who feel isolated. A reciprocal mechanism might also occur – as a co-curricular activity, ambassador outreach may promote perceptions of support within the social context of an engineering cohort. Therefore, items on engineering retention and climate from the *Project to Assess Climate in Engineering* [34] and two *Assessing Women and Men in Engineering* surveys [35, 36] were adapted for inclusion in the Ambassador Questionnaire.

2.3 Professional Communication Skills

Professional communication and leadership capabilities are valued by employers. Communication skills are explicitly listed included in the body of knowledge expected of a professional engineer [37, 38], and the National Society for Professional Engineers emphasizes communication to technical and nontechnical audiences in its domain of professional practice. Leadership skills such as acceptance of constructive criticism and an ability to establish trust and collaboration among a group of peers are essential for early career success in the workplace [39]. Historically, however, engineering degree programs have found it to be challenging to implement curriculum-wide professional communication initiatives, in part because of the relatively inauthentic way such skills are used in coursework settings compared to professional or nontechnical situations [40].

Professional communication skills are highly relevant to the outreach ambassador role. Studies of outreach programs including ambassador training workshops, K-12 outreach summer camps, and high school mentoring programs note that when required to learn how to present to younger or nontechnical audiences, undergraduate students report increases in their technical communication skill and confidence [41–43]. In one study of ambassadors' perceptions of outreach, Talbot and colleagues [44] found that 95 percent of ambassadors reported increased confidence in presenting engineering content, and 75 percent reported that developing an outreach presentation left them prepared to transfer engineering content knowledge across topic areas. In another study, Alley and colleagues [45] noted that between 65 and 75 percent of newly trained ambassadors felt more confident in specific communication skills such as creating visual aids that help an audience understand information and knowing which details to include or omit from a technical presentation. Other studies in which undergraduate students were interviewed after giving outreach presentations at summer camps and mentoring programs found that students not only reported increases in understanding the material, but that outreach influenced their confidence towards communicating with co-workers in the future [46, 47].

3. Summary

Theoretical and practical perspectives suggest that outreach participation provides an opportunity for undergraduate students to align and/or bolster their self-efficacy, beliefs and motivation towards engineering, and self-perceptions as a messenger of technical information. Qualitative evidence suggests that these psychological components of the ambassador role are supported by the social context and foster the development of a coherent sense of self in this role. However, there is a gap in our understanding of how these constructs relate, how they may shift over time in ambassadors, how they are selected for or otherwise develop through sustained engagement in outreach, and how they manifest for subgroups including females, racial and ethnic minorities, and first-generation college students. The Ambassador Questionnaire is designed to help address this gap and, in its final form, sit alongside program-specific measures that gather students' perceptions and impressions of particular outreach program structures and practices.[2]

3.1 Research Objectives

In educational research disciplines, multi-construct and omnibus measures are often created for the purpose of parsimonious assessment of individuals before and after interventions, and to evaluate the effectiveness of various program components [48–50]. Thus, our research objectives were to:

1. Create a draft instrument by creating and adapting items identified as being relevant to outreach impact, including the constructs of

[2] The development of a measure is a necessary precursor to the long-term goal of assessing the impact of being an ambassador. We did not focus on establishing whole- or sub-group norms or consider longitudinal changes in scores associated with sustained outreach participation. We also consider program-specific topics such as students' motivation to join a particular outreach club or organization to be beyond the scope of the measure.

academic confidence, engineering career motivation, engineering beliefs, professional skills, and social supports.
2. Administer the measure to undergraduates engaged in engineering outreach and use psychometric analytic approaches to examine its content and construct validity, and internal consistency reliability.
3. Present a revised measure that can be used in K-12 engineering outreach research, program management, and program evaluation.

4. Methods

The measure development process, adapted from Boateng, Neilands, Frongillo, Melgar-Quiñonez and Young [51] is depicted graphically in Fig. 1. First, data from two focus groups and conference calls with representatives of 19 Engineering Ambassador programs were used to understand practitioners' perspectives on measuring ambassadorship impact. In these meetings, chapter leaders responded to and discussed questions about the features of their programs they considered important for ambassadors' professional development, the ways in which their students seemed to manifest change, and particular activities or chapter components that contributed to change. Responses revealed consensus about the impact of formal training, acting in the role of mentor, contributing to the governance of the chapter, and conducting community outreach. Leaders provided anecdotal evidence about the perceived impact on students in the areas of engineering motivation, self-efficacy, technical communication skills, beliefs about the field of engineering, and plans to join the field upon graduation. However, the findings also revealed a lack of consistent, standardized tools for capturing ambassadors' self-perceptions and beliefs. Leaders expressed challenges in systematically evaluating the impact of these components on ambassadors and expressed interest in accessing a single evaluation tool that could be used across the Network. These initial activities established both the need for and the utility of the measure from the perspective of potential end users.

Due to this consensus and prior, qualitative studies [8], we determined the component constructs to be a well-defined domain. As such, phase one included a literature review of survey items in related domains and deductive item development.

4.1 Phase I. Instrument Development and Expert Panel Review

The literature review revealed several existing resources closely aligned with our purpose, including the *Longitudinal Assessment of Engineering Self-Efficacy* (LAESE) [36], the *Project to Assess Climate in Engineering* (PACE) survey [34], the *Laanan Transfer Students Questionnaire* (L-TSQ) [52], the *National Academy of Engineering Changing the Conversation Survey* [14], *Assessing Women and Men in Engineering* (AWE) retention surveys [35, 36] the *National WEPAN Climate Survey* [53] and the *Engineering Ambassador workshop survey and exit interviews* [54, 55].

Questions were organized thematically to yield

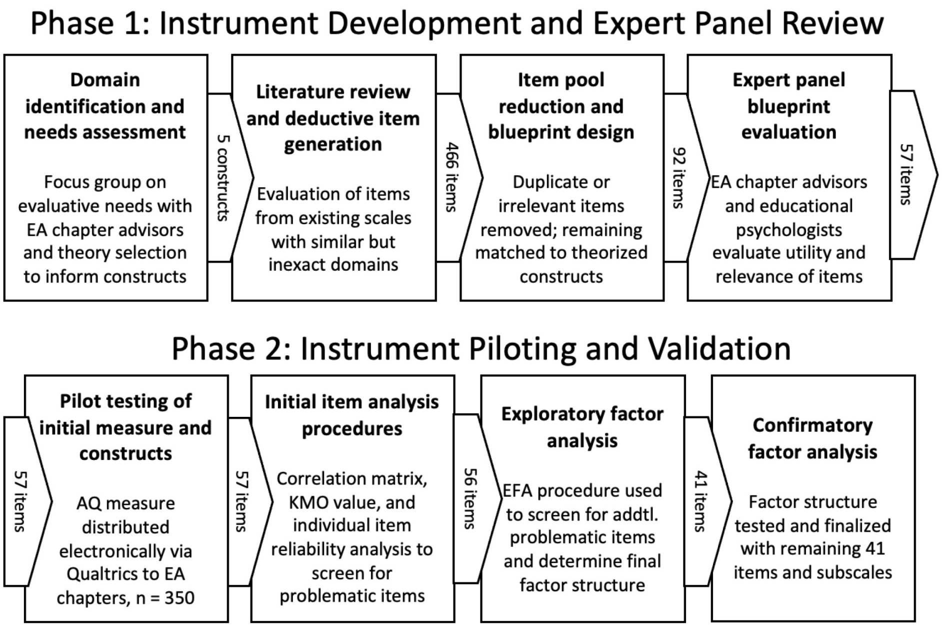

Fig. 1. Measure development process.

Table 1. Theorized subscales with sample items

Subscale	Item
Academic Confidence (AC)	"I am confident I can succeed in my engineering courses."
Engineering Career Interest and Motivation (ECM)	"Someone like me can succeed in an engineering career."
Engineering Beliefs (EB)	"Engineers help to make the world a better place."
Professional Skills (PS)	"I can deliver engaging outreach presentations."
Social Supports (SS)	"It is easy for me to make friends."

466 items. Duplicate and irrelevant items, such as items pertaining to transfer students or specific course experiences, were removed. For consistency, items were restructured to align with a five-point Likert-style agreement scale, and several items were also modified to reflect the context of engineering outreach activities specifically. Items were then grouped according to the literature themes and prior studies on ambassador professional identity development [10]. The tentative blueprint presented for expert review was as follows: Academic Confidence (19 items), Engineering Career Interest and Motivation (12 items), Engineering Beliefs (13 items), Professional Skills (28 items), and Social Supports (20 items). Five demographic items were also included to allow for analysis by gender and racial-ethnic identity and other identifiers (year in school, college, or university). Four open-ended items pertaining to students' ambassadorship experiences and goals were included on the measure but were not incorporated in the psychometric analyses. Item exemplars are presented in Table 1.

Next, to enhance content and face validity, we engaged an expert panel of subject area specialists [45] to review the 92 items measure. The panel was composed of four Engineering Ambassadors Network chapter advisors from public and private universities and one independent educational researcher who was familiar with the EAN model and training program. To assess items for content validity and alignment with the goals of the measure, the experts used a five-point Likert-style scale with response options ranging from "not at all important" to "very important" and were also able to provide written feedback at the end of each theorized subscale as needed. Interrater reliability for expert panel ratings was then calculated using a two-way mixed effects consistency model [56] and revealed an acceptable ICC value of 0.71[3].

The expert panel recommended retention of 66 of the 92 items. Upon further review by the research team, an additional nine items were removed due to either a lack of alignment with the intent of the measure or being duplicative or vague. This resulted in a 57-item pilot measure: 12 items were anticipated to align with Academic Confidence (AC), 11 items were grouped under the topic of Engineering Career Motivation (ECM), 10 items were aligned with Engineering Beliefs (EB), 15 items associated with Professional Skills (PS), and nine items were consistent with Social Supports (SS). Appendix Table A1 includes a full list of items and the theorized subscales; appendix A2 includes the validated measure with its demographic queries.

4.2 Phase II. Instrument Piloting and Validation

Following human subjects approval, the measure was administered in three waves during fall of the 2018–2019, 2019–2020, and 2021–2022 academic years. Participants responded using an online Qualtrics form which was distributed to various engineering ambassador chapters at 27 colleges/universities. Chapter leaders provided the link to their respective ambassadors.

To ensure there were not significant differences between year of administration, race/ethnicity, and gender, statistical analyses were conducted using total scale score as the outcome variable. Year of administration did not affect total scale score, as revealed by a one-way analysis of variance (ANOVA) ($F(2, 347) = 0.56$, $p = 0.57$). A small percentage of students ($n = 11$; 3%) participated in the repeated administrations, but as the measure is intended to accommodate year-over-year responses by individuals as students matriculate through their college experience, we opted to leave this small number of responses in the dataset. No statistically significant differences were observed for total scale score by gender ($t_{(342)} = 1.01$, $p = 0.32$) nor by race/ethnicity ($F_{(6,\ 343)} = 0.19$, $p = 0.98$).

4.3 Analysis Sample

The analytical sample included responses from 350 ambassadors, more than half of whom were female (63.4%, $n = 222$) or white (63.1%, $n = 221$). Thirteen percent ($n = 46$) of participants identified as Asian, with 10.0% ($n = 35$) identifying as Latinx, 5.7% ($n = 20$) identifying as African American, and 6.6% ($n = 23$) identifying as Multiracial. Five participants self-identified their ethnicity through a write-in response or opted to not respond.

In our sample, 2.6% ($n = 9$) were freshmen, 35.7%

[3] One rater's numerical responses were not used due to incomplete numerical ratings for one-third of the items, but this rater's written comments were considered in item selection.

(n = 125) were sophomores, 32.9% (n = 115) were juniors, and 24.9% (n = 87) were seniors. A small number (n = 13) or 3.7% indicated "other" and one respondent did not identify their year in college. Many participants were serving for the first time as an ambassador (68.3%, n = 239), but 31.7% were experienced ambassadors: 19.4% (n = 68) were second-year ambassadors, 9.4% (n = 33) were third-year ambassadors, and 2.9% (n = 10) were fourth- or more year ambassadors.

4.4 Analytic Approach

We used exploratory and confirmatory factor analyses to establish construct validity and support content validity [57]. The first step in this process was to randomly split the data into two groups [58]; this procedure was performed by generating random numbers in SPSS and splitting the dataset equally using the median random number as a separator. Randomized splits of the data were examined to ensure that no differences between the data sets were present, such as differences between gender, race/ethnicity, years as an ambassador, and year of assessment. There was no difference found between the two randomized data splits in gender ($t(348) = –0.42$, $p = 0.67$), race/ethnicity ($t(348) = –0.91$, $p = 0.37$), years as an ambassador ($t(334.02) = 0.69$, $p = 0.49$) nor year of assessment ($t(348) = –1.25$, $p = 0.21$). There was also no difference found between the two randomized data splits on composite score for the pilot scale ($t(348) = –0.06$, $p = 0.95$). We then conducted an exploratory factor analysis (EFA) using Principal Axis Factoring with one dataset to examine the factor structure and a confirmatory factor analysis (CFA) with the second dataset to validate the findings that resulted from the EFA and examine model fit [59]. Finally, we calculated Cronbach's alpha coefficients to examine internal consistency to

Table 2. AQ items means and standard deviations

Item	*M*	*SD*	Item	*M*	*SD*
AC1	4.41	0.60	EB30	4.16	0.80
AC2	4.50	0.61	EB31	4.66	0.52
AC3	4.64	0.56	EB32	4.46	0.65
AC4	4.33	0.74	EB33	4.75	0.55
AC5	3.97	0.99	PS34	4.41	0.62
AC6	4.53	0.72	PS35	4.45	0.55
AC7	4.63	0.58	PS36	4.41	0.58
AC8	4.25	0.75	PS37	4.39	0.59
AC9	4.26	0.75	PS38	4.36	0.61
AC10	4.24	0.82	PS39	4.42	0.60
AC11	4.31	0.77	PS40	4.38	0.63
AC12	4.61	0.61	PS41	4.30	0.71
ECM13	4.62	0.61	PS42	4.24	0.72
ECM14	4.51	0.61	PS43	4.46	0.62
ECM15	4.52	0.63	PS44	3.94	0.83
ECM16	4.42	0.65	PS45	4.27	0.73
ECM17	4.57	0.55	PS46	4.28	0.65
ECM18	4.34	0.78	PS47	4.28	0.73
ECM19	3.77	0.95	PS48	4.61	0.50
ECM20	3.71	1.03	SS49	4.49	0.67
ECM21	4.33	0.70	SS50	4.35	0.78
ECM22	4.29	0.73	SS51	4.36	0.77
ECM23	4.30	0.78	SS52	3.91	1.04
EB24	4.48	0.61	SS53	4.14	0.86
EB25	4.77	0.43	SS54	4.59	0.54
EB26	4.63	0.56	SS55	4.43	0.65
EB27	4.73	0.47	SS56	3.87	0.97
EB28	4.70	0.52	SS57	4.56	0.55
EB29	4.75	0.45			

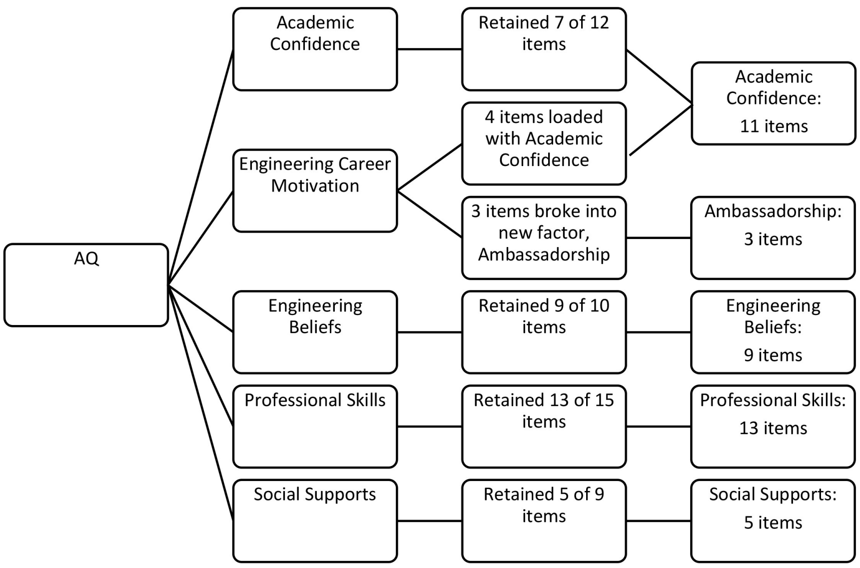

Fig. 2. Progression of Ambassador Questionnaire structure and analysis-informed changes.

support the reliability of the measure. Means and standard deviations for the 57 AQ items prior to the split are presented in Table 2. Please refer to appendix A1 and A2 for details on item content.

5. Results

5.1 Construct Validity of the Ambassador Questionnaire

Exploratory factor analysis. Diagnostic procedures prior to splitting the dataset revealed that one item (AC6) exhibited excessively low inter-item correlations. This item had inter-item correlation values of 0.20 – 0.85 with less than ten other items. Following the guidance of Field [57] this item was removed from further analysis. The Kaiser-Meyer-Olkin value of the remaining items was 0.90, indicating sufficient sampling adequacy. Bartlett's test of sphericity ($p > 0.001$) revealed that the correlations among the remaining items were acceptable.

The data were randomly split and the initial EFA was conducted with one of the randomly split sets. We used principal axis factoring with Varimax rotation and forced five factors to align with anticipated subscales (a preliminary scree plot analysis also indicated five factors). A total of 15 additional items (AC4, AC5, AC8, AC9, ECM17, ECM18, ECM19, ECM20, EB30, PS34, PS48, SS49, SS53, SS54, SS57) were removed one by one for low factor loading values (< 0.40) or notable cross-loading between two or more factors (> 0.40). The final EFA with 41 items explained 52.6% of the variance with 5 extracted factors.

We retained the anticipated subscales of Academic Confidence, Engineering Beliefs, Professional Skills, and Social Supports. The Engineering Career Motivation subscale did not hold; some items loaded on Academic Confidence and some items broke into their own factor which we labeled Ambassadorship (see Fig. 2). Table 3 presents EFA factor loadings for the 41 retained items.

Table 3. Rotated factor loadings by theorized subscales for 41 retained items

Item	PS	EB	AC	SS	AMB
PS42	0.83				
PS46	0.77				
PS41	0.77				
PS44	0.69				
PS47	0.67				
PS45	0.67				
PS40	0.66				
PS39	0.54				
PS43	0.44				
PS36	0.42				
PS35	0.41				
PS37	0.41				
PS38	0.41				
EB31		0.80			
EB29		0.78			
EB25		0.75			
EB27		0.70			
EB28		0.68			
EB32		0.60			
EB24		0.65			
EB26		0.60			
EB33		0.43			
AC12			0.72		
AC1			0.69		
AC10			0.67		
ECM13			0.62		
AC2			0.59		
AC7			0.55		
AC3			0.55		
ECM14			0.55		
ECM16			0.55		
AC11			0.54		
ECM15			0.42		
SS51				0.75	
SS50				0.75	
SS56				0.52	
SS52				0.49	
SS55				0.44	
ECM23					0.72
ECM21					0.66
ECM22					0.62

Confirmatory Factor Analysis. A CFA with the 41 retained items was then conducted with the second randomized dataset. This allowed for validation of the factor structure that emerged from the EFA as well as examining model fit and exploring covariances between factors. The CFA revealed statistically significant factor loadings for each of the five factors, with standardized regression weight values ranging from 0.53–0.75 for Academic Confidence, 0.37–0.82 for Engineering Beliefs, 0.48–0.69 for Social Supports, 0.42–0.75 for Professional Skills, and 0.79–0.86 for Ambassadorship (see Figs. 3–7 and Table 4). The squared multiple correlation values, which explain the amount of variance accounted for by the common factor for each of the items, ranged from 0.28 to 0.57 for Academic Confidence, 0.13–0.67 for Engineering Beliefs, 0.23–0.48 for Social Supports, 0.18–0.56 for Professional Skills, and from 0.37 to 0.68 for the Ambassador subscale. This indicates that the factors explained an adequate portion of item variance (see Table 5).

Model fit. While guidance varies [60], the χ^2 statistic and Comparative Fit Index are often used to indicate model fit. Our findings revealed a statistically significant χ^2 (1,411.76, $df = 769$, $p <$

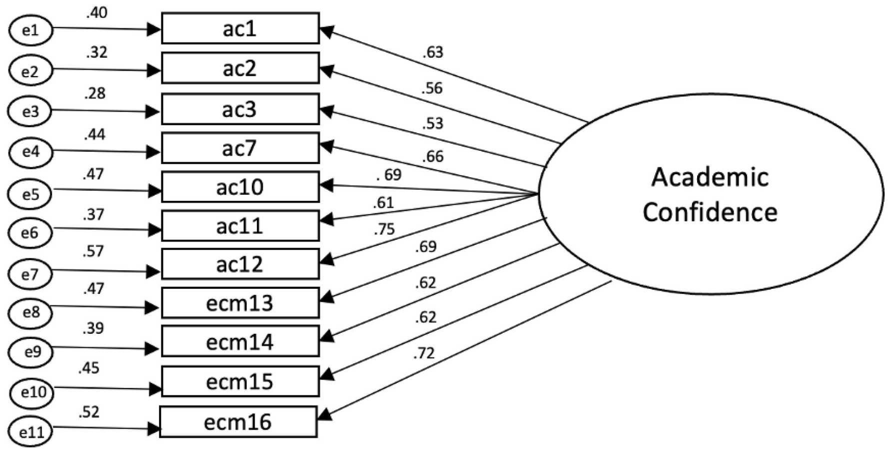

Fig. 3. Academic Confidence factor structure.

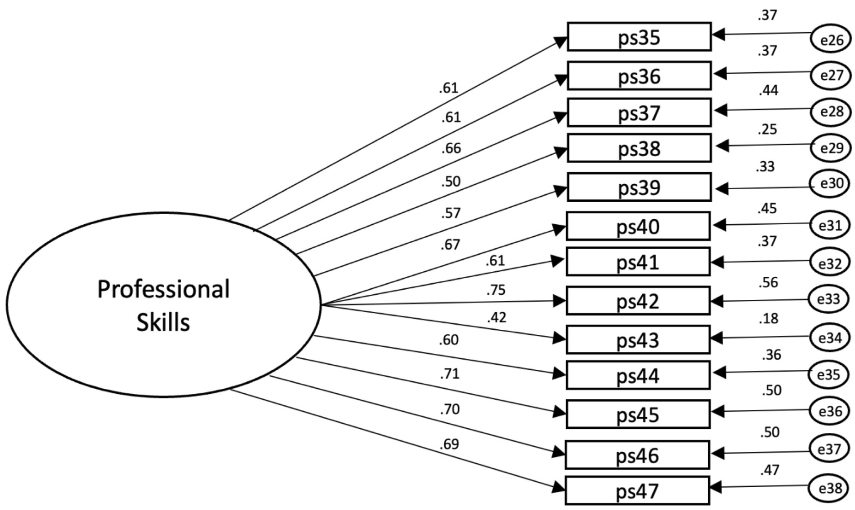

Fig. 4. Professional Skills factor structure.

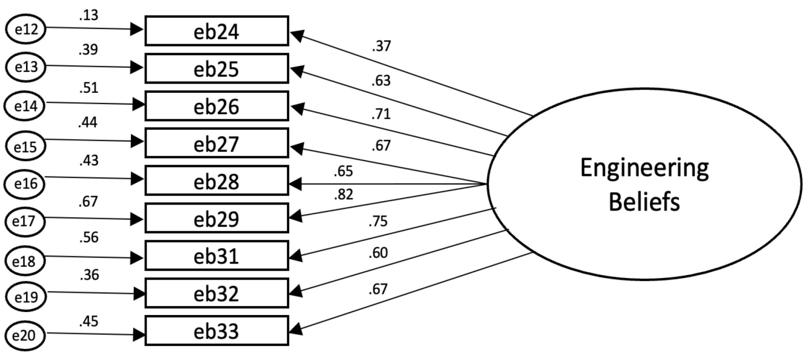

Fig. 5. Engineering Beliefs factor structure.

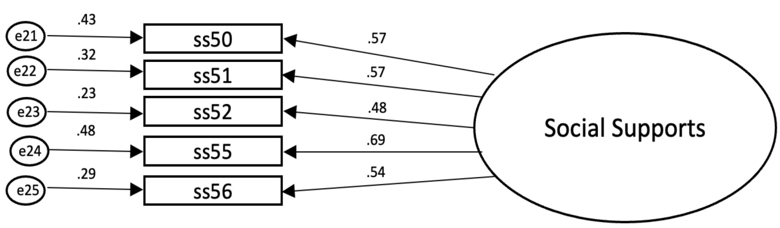

Fig. 6. Social Supports factor structure.

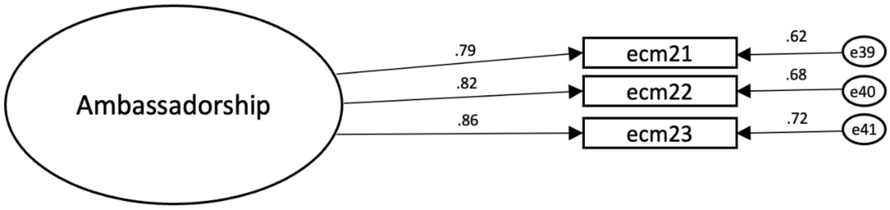

Fig. 7. Ambassadorship factor structure.

Table 4. Standardized regression weights following the confirmatory factor analysis

Item	PS	EB	AC	SS	AMB
PS35	0.61				
PS36	0.61				
PS37	0.66				
PS38	0.50				
PS39	0.57				
PS40	0.67				
PS41	0.61				
PS42	0.75				
PS43	0.42				
PS44	0.60				
PS45	0.71				
PS46	0.70				
PS47	0.69				
EB24		0.37			
EB25		0.63			
EB26		0.71			
EB27		0.67			
EB28		0.65			
EB29		0.82			
EB31		0.75			
EB32		0.60			
EB33		0.67			
AC1			0.63		
AC2			0.56		
AC3			0.53		
AC7			0.66		
AC10			0.69		
AC11			0.61		
AC12			0.75		
ECM13			0.69		
ECM14			0.62		
ECM15			0.67		
ECM16			0.72		
SS50				0.57	
SS51				0.57	
SS52				0.48	
SS55				0.69	
SS56				0.54	
ECM21					0.79
ECM22					0.82
ECM23					0.86

Table 5. Squared multiple correlations following the confirmatory factor analysis

Item	PS	EB	AC	SS	AMB
PS35	0.37				
PS36	0.37				
PS37	0.44				
PS38	0.25				
PS39	0.33				
PS40	0.45				
PS41	0.37				
PS42	0.56				
PS43	0.18				
PS44	0.36				
PS45	0.50				
PS46	0.50				
PS47	0.47				
EB24		0.13			
EB25		0.39			
EB26		0.51			
EB27		0.44			
EB28		0.43			
EB29		0.67			
EB31		0.56			
EB32		0.36			
EB33		0.45			
AC1			0.40		
AC2			0.32		
AC3			0.28		
AC7			0.44		
AC10			0.47		
AC11			0.37		
AC12			0.57		
ECM13			0.47		
ECM14			0.39		
ECM15			0.45		
ECM16			0.52		
SS50				0.43	
SS51				0.32	
SS52				0.23	
SS55				0.48	
SS56				0.29	
ECM21					0.62
ECM22					0.68
ECM23					0.72

Table 6. Correlation between factors following the confirmatory factor analysis

Factor	AC	EB	SS	PS	AMB
AC	–				
EB	0.47***	–			
SS	0.59***	0.50***	–		
PS	0.62***	0.36*	0.53***	–	
AMB	0.52***	0.46***	0.49***	0.38***	–

*$p < 0.05$, *** $p < 0.001$.

0.001), suggesting that the model was not a good fit to the data. The CFI for this analysis was 0.84, which is to be expected with large and complex models [61]. However, a more suitable indicator of model fit for intricate structural equation models is the root mean square error of approximation (RMSEA). The RMSEA for our analysis was 0.06, indicating adequate model fit [62] and allowing the structure to be retained.

Table 6 provides the correlations between the five factors, which were positive and statistically significant. The highest correlation among factors was found for Academic Confidence and Professional Skills ($r = 0.62$), followed by Academic Confidence and Social Supports ($r = 0.59$). The Ambassadorship factor correlated highest with Academic Confidence ($r = 0.52$), followed by Social Supports ($r = 0.49$). Notably, the lowest correlations were found between Engineering Beliefs and Professional Skills ($r = 0.36$), and between Professional Skills and Ambassadorship ($r = 0.38$).

5.2 Internal Consistency Reliability

We calculated Cronbach's alpha coefficients to examine internal consistency reliability for a total scale score and for each factor as a subscale. The whole scale coefficient was 0.94 and the subscale coefficients ranged from 0.72 to 0.90 (see Table 7). These coefficients exceed the 0.70 level of acceptability for internal consistency reliability [57] and support the internal consistency reliability of the Ambassador Questionnaire and five resulting factors: Academic Confidence, Engineering Beliefs, Professional Skills, Social Supports, and Ambassadorship.

Table 7. Cronbach's alpha coefficients by scale and subscale

Scale/subscale	Cronbach's Alpha
Academic Confidence	0.89
Engineering Beliefs	0.89
Social Supports	0.72
Professional Skills	0.90
Ambassadorship	0.90
Whole Scale	0.94

6. Discussion

Researchers, program evaluators, and outreach leaders currently lack a comprehensive tool for assessing the engineering related beliefs and self-perceptions of undergraduate students who perform K-12 outreach. Similarly, to our knowledge, the constructs included in the Ambassador Questionnaire have not been assessed in a single sample of undergraduate students who are engaged in K-12 engineering outreach. Our research yielded a valid and reliable scale that includes five moderately correlated subscales: academic confidence, engineering beliefs, social supports, professional skills, and ambassadorship. We now consider how our findings relate to the extant literature on engineering student professional growth and suggest ways in which the AQ might facilitate the development of a coherent theoretical framework for understanding the role of outreach ambassador. Then, we discuss implications for those who manage and evaluate engineering outreach, and close with limitations of the study.

6.1 Ambassadors' Beliefs about Engineering as a Domain and a Professional Field

The confirmed structure of the AQ revealed that the constructs measured were in line with the messages included in the NAE *Changing the Conversation* report with which many Engineering Ambassadors Network outreach presentations are aligned; further, participants expressed beliefs that engineering helps to make the world safer and healthier, and that diversity is important. More broadly, this echoes other studies that have described how engineering students, and particularly students from historically underrepresented groups, are likely to express a personal interest and motivation towards engineering that is rooted in outreach-appropriate prosocial messages (NAE, 2008). Some students may be attracted to outreach organizations because they convey values that align with personal goals of impacting the community and professional goals of becoming an engineer [11, 29, 31, 63]. Prosocial messages about diversity in engineering may resonate for students who consider these values to be foundational to their motivation for a career in the field [12]. However, it remains to be seen whether students' beliefs become more aligned with outreach messages over time, or if outreach programs tend to select students with such beliefs. If administered in a repeated fashion to ambassadors and non-ambassadors, the AQ could serve as a tool for exploring these questions.

The AQ also demonstrated promise for identifying areas of perceived inequity among future engineers. Despite broadly positive beliefs about the

discipline and high ratings of academic self-confidence, the students in our sample reported slightly lower scores for items pertaining to equitable pay and opportunities for advancement in the engineering field. Researchers studying attrition from undergraduate engineering programs have noted that when some underrepresented populations such as women leave an engineering major, they are likely to have low levels of academic and career self-efficacy and lower expectations for success in the profession [64]. Lower expectations for success may be accompanied by a heightened perception of inequality. The role that outreach participation may play in the career self-efficacy of different groups of students has not been widely studied, but the AQ may be helpful in studying whether designing and delivering outreach messages may impact female and historically underrepresented ambassadors' academic confidence and expectations for success in the workplace, or in detecting students who may be at risk of anticipating marginalization or isolation in the workplace. Since some students may be predisposed to possess beliefs and self-perceptions that hinder their persistence in the field [12, 65], the AQ might help to clarify whether outreach can function as a supportive context for students who are at-risk due to discrepancies between their academic performance and their sense of belonging.

6.2 Outreach as a Context for Developing Retention-oriented Identities

The undergraduate STEM experience serves as a context for exploring the self and internalizing various social roles [66–68]. When students perform outreach, they engage in a co-curricular activity in which they adopt the role of engineering ambassador. This role differs from their typical role of undergraduate student and evokes novel possibilities for action such as talking with and mentoring younger students, creating and delivering engaging presentations and demonstrations to nontechnical audiences, representing their college of engineering, and conveying the importance of diversity in the STEM workforce. Because acting in a social role has implications for how one views oneself, and how one is viewed by others, performing outreach in the formal role of an ambassador may bolster motivation toward degree completion and a career in the field [11, 69]. With time, students may incorporate ambassador role components into their overall sense of identity as a professional engineer [25, 65, 70, 71].

The AQ includes constructs that are commonly included in psychosocial perspectives on engineering identity such as academic and career self-efficacy, engineering related beliefs, and perceptions of the self in an expert role [22, 72]. It is aligned with research that has connected academic self-perceptions and motivations, and an awareness (through action) that others see them as an engineering or STEM person, with the development of a robust STEM identity [10, 72–74]. STEM degree completion has been associated with the interplay among the type of self-perceptions, outcome expectancies, and worldviews that are included in the AQ [18, 19, 74].

Students' identification with a professional STEM role has been known to change as students matriculate through their degree programs and experience both academic and social successes and challenges in varying contexts [75]. Co-curricular program participation may be one context that can foster positive self-perceptions, beliefs, and professional expectations for the field of engineering. Developing and delivering outreach messages may promote changes in students' academic confidence, and engineering-related technical and interpersonal communication skills. It is also plausible that students may experience changes in career self-efficacy and become more aware of, or even more favorable towards, values and beliefs that reflect the outreach mission [29, 31]. Students may also find that the social context of the outreach group provides near-peer support that promotes persistence in a degree program and social recognition. Our findings support the AQ as a measure that can adequately assess these concepts for data-driven decision-making regarding programming efforts and continued support of ambassadors. Our findings are aligned with other research such as Bergeson and colleagues [11] who found that outreach participation influenced engineering students' gains in self-perceptions as engineers and purveyors of engineering content, personal beliefs and values for an anticipated career in engineering, and satisfaction in achieving the goal of raising others' interests in engineering careers. Gains were accompanied by actions in the role of connecting engineering concepts with real world topics and confidently communicating with non-technical audiences. Accordingly, we noted positive correlations among the five subscales, which measured similar attributes. Future research efforts using the AQ could build on these findings and explore ambassadorship as a context for undergraduate students' identity formation in more detail. The prior evidence to suggest that the ambassador role supports the development of students' engineering identity is promising, but the AQ will allow researchers to consider this question at scale.

6.3 Practical Implications

The present work was undertaken in the interests of

both theory and practice. Outreach is often included in college or grant-funded engineering education initiatives, and outreach leaders or those evaluating outreach programs may be interested in using the AQ in a pre/post fashion over the course of one or more academic years. As a pre-assessment, the AQ might offer insights into the current needs for a particular cohort of outreach ambassadors. As a post- or follow-up assessment, the AQ could be used to reveal changes in these students as well as to offer insights into areas of strength or challenge for a program. The impact of interventions to develop components of a program could then be captured through changes in students' AQ responses, and outcomes could be meaningfully compared across groups within or between different outreach models.

If administered to the general student body in engineering degree programs, aggregate AQ scores could provide information about various groups of students including those who are engaged in other, similar co-curricular activities such as service learning. Composite subscale or individual item scores could be used as well to check for potential response pattern differences that highlight students' perceptions of equity issues. Scores could also be used in conjunction with exit interviews to gain insights into students' expectations regarding the professional workforce. This information may prove useful for large engineering programs as it could detect differences in the perceptions of particular participants such as women and underrepresented racial and ethnic groups in STEM that could be addressed through responsive programming. Although developed in the context of the Engineering Ambassadors Network, the use of the AQ is not limited to this context; rather, we hope that it will be used in longitudinal and cross-sectional research and program evaluation efforts to understand how engineering outreach can impact students, perhaps in tandem with measures of the effect of the outreach on the K-12 students in the context of broader conversations about identity formation [75–79].

6.4 Limitations

The instrument development and dimension reduction procedures in this study provide evidence of the construct validity of the AQ scale. However, to manage response burden and focus on construct validation we chose not to establish concurrent validity in this study by administering additional measures. Admittedly, this limits our ability to draw conclusions between AQ scores and other measures such as those that draw more explicitly on particular models of engineering identity or particular types of engineering career intentions. A second limitation is the lack of outcome measures such as course grades or graduation rates for seniors, and the lack of objective information about the amount and type of outreach conducted by respondents. We were unable to triangulate our data with outreach participation, and hope that future research will do this with a view to providing evidence for the predictive validity of the measure. A final limitation is the self-selected nature of the sample, which may not be representative of the broader population of undergraduate engineering students. Additional validation studies may be needed in order to provide information about how the measure performs in contexts where students conduct outreach that does not include professional and technical skills training, or contexts outside of U.S. K-12 and higher education systems.

7. Conclusion

In this study, we used a multi-step approach to develop an omnibus assessment of ambassadors' self-perceptions, beliefs, and perceptions of the current and future context of their engineering experiences that, we hope, is also flexible enough to be able to capture changes associated with outreach participation. We administered the AQ to a large and diverse group of undergraduate engineering students and used the data to demonstrate its construct validity. Four of the five subscales were moderately correlated with one another, suggesting both uniqueness and meaningful overlap and alignment between students' academic confidence, engineering beliefs, social supports, and professional skills. The factor structure is aligned with prior qualitative work on ambassadors' self-perceptions and their emerging role identities as ambassadors for the field, as well as the broader literature on the formation of diverse students' engineering identities. The fifth subscale, ambassadorship, was less strongly correlated with the others, but represents a contextually specific measure of students' expectations about the ambassador role that could be of use to program advisors and those seeking to evaluate different models of outreach.

The AQ may be adapted to other forms of ambassadorship including STEM, STEM-H (Health Sciences), and STEM+C (Computer Science) ambassadors. If used in large scale research, we hope that the AQ can contribute to national efforts to understand the effect of equipping diverse groups of undergraduate students with the knowledge, skills, and motivations to meaningfully change the conversation about the field of engineering.

Acknowledgements: A preliminary phase of this research was supported by the National Science Foundation under EAGER #1752096.

References

1. G. C. Orsak, Guest editorial: K-12: Engineering's new frontier, *IEEE Transactions on Education*, **46**(2), pp. 209–210, 2003.
2. B. Moskal and C. Skokan, Supporting the K-12 classroom through university outreach, *Journal of Higher Education Outreach and Engagement*, **15**(1), pp. 53–75, 2011.
3. L. Nadelson and J. Callahan, A comparison of two engineering outreach programs for adolescents, *Journal of STEM Education*, **12**(1), pp. 43–54, 2011.
4. P. Molina-Gaudo, S. Baldassarri, M. Villarroya-Gaudo and E. Cerezo, Perception and intention in relation to engineering: A gendered study based on a one-day outreach activity, *IEEE Transactions on Education*, **53**(1), pp. 61–70, 2010.
5. R. Habash and C. Suurtamm, Engaging high school and engineering students: A multifaceted outreach program based on a mechatronics platform, *IEEE Transactions on Education*, **53**(1), pp. 136–143, 2010.
6. A. Sahin, STEM clubs and science fair competitions: Effects on post-secondary matriculation, *Journal of STEM Education: Innovations and Research*, **14**(1), pp. 5–11, 2013.
7. S. Wei and T. Wonch Hill, An evaluation on engineering identity of K-12 youth using the Engineering Ambassador Network, *the ASEE Annual Meeting and Exposition*, Salt Lake City, UT, United States, June 2018.
8. J. K. Garner, M. Alley and M. G. Kuhn, Common practices in undergraduate engineering outreach, *the ASEE Annual Meeting and Exposition*, Tampa, FL, United States, June 2019.
9. M. Alley, K. Thole and J. K. Garner, Final: Creating a national network of engineering ambassadors: A professional development program with an outreach mission. Submitted to the National Science Foundation upon completion of award # 132320. Personal communication, 2018.
10. J. K. Garner, C. Haas, M. Alley and A. Kaplan, The emergence of outreach ambassador role identities in undergraduate engineering students, *Journal of STEM Outreach*, **1**(2) pp. 1–18, 2018.
11. A. A. Bergeson, B. K. Hotchkins and C. Furse, Outreach and identity development: New perspectives on college student persistence, *Journal of College Student Retention: Research, Theory & Practice*, **16**(2), pp. 165–185, 2014.
12. K. Litchfield and A. Javernick-Will, "I am an engineer AND": A mixed methods study of socially engaged engineers, *Journal of Engineering Education*, **104**(4), pp. 393–416, 2015.
13. K. A. Thole, S. E. Zappe, M. Marshall, M. Alley and R. S. Engel, Engineering Ambassadors Network: Dissemination through an inaugural national workshop, the ASEE Annual Conference and Exposition, Atlanta, GA, United States, June 2013.
14. National Academy of Engineering Committee on Public Understanding of Engineering Messages, *Changing the Conversation: Messages for Improving Public Understanding of Engineering*, The National Academies Press, Washington, D.C., United States, 2008.
15. S. Jordan-Bloch and S. Cohen, Engagement in practice: Infusing the STEM pipeline through community engaged learning, *the ASEE Annual Conference and Exposition*, Salt Lake City, UT, United States, June 2018.
16. S. Zappe, M. Marshall, E. D. Gomez, E. Gomez and A. D. Lueking, Using student ambassadors to relay themes from Changing the Conversation in engineering first year seminars, *the ASEE Annual Conference and Exposition*, San Antonio, TX, United States, June 2012.
17. Z. Hazari, G. Sonnert, P. M. Sadler and M-C Shanahan, Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study, *Journal of Research in Science Teaching*, **47**(8), pp. 978–1000, 2010.
18. V. Papafilippou and L. Bentley, Gendered transitions, career identities and possible selves: the case of engineering graduates, *Journal of Education and Work*, **30**(8), pp. 827–839, 2017.
19. C. Tendhar, M. C. Paretti and B. D. Jones, The effects of gender, engineering identification, and engineering program expectancy on engineering career intentions: Applying hierarchical linear modeling (HLM) in engineering education research, *American Journal of Engineering Education*, **8**(2), pp. 157–170, 2017.
20. H. L. Greene, P. E. Post and L. Abrams, Engineering ambassador program connects high school students with university students and career engineers in their communities, *the ASEE Annual Conference and Exposition*, Seattle, WA, United States, June 2015.
21. R. J. McFalls, C. D. Grimes, M. J. Mohammad-Aragh, R. W. Sullivan and J. Warnock, Undergraduate facilitators' perspectives of engineering summer programs, *the ASEE Annual Conference and Exposition*, Seattle, WA, United States, June 2015.
22. A. Bandura, *Social Foundations of Thought and Action: A Social Cognitive Theory*, Prentice Hall, Hoboken, NJ, United States, 1986.
23. E. Litzler, C. C. Samuelson and J. A. Lorah, Breaking it down: Engineering student STEM confidence at the intersection of race and gender, *Research in Higher Education*, **55**(8), pp. 810–832, 2014.
24. R. M. Marra, K. A. Rodgers, D. Shen and B. Bogue, Women engineering students and self-efficacy: A multi-year, multi-institution study of women engineering student self-efficacy, *Journal of Engineering Education*, **98**(1), pp. 27–38, 2009.
25. R. M. Marra and B. Bogue, Women engineering students' self-efficacy: A longitudinal multi-institution study, *Women in Engineering Programs and Advocates Network (WEPAN) Conference*, Pittsburg, PA, USA, June 2006.
26. T. J. Yosso, Whose culture has capital? A critical race theory discussion of community cultural wealth, *Race Ethnicity and Education* **8**(1), pp. 69–91, 2005.
27. S. Conrad, S. S. Canetto, D. MacPhee and S. Farro, What attracts high-achieving, socioeconomically disadvantaged students to the physical sciences and engineering? *College Student Journal*, **43**(4), pp. 1359–1369, 2009.
28. H. M. Matusovich, R. A. Streveler and R. L. Miller, Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values, *Journal of Engineering Education*, **99**(4), pp. 289–303, 2010.
29. A. Godwin and A. Kirn, Identity-based motivation: Connections between first-year students' engineering role Identities and future-time perspectives, *Journal of Engineering Education*, **109**(3), pp. 362–383, 2020.
30. D. Oyserman, Identity-based motivation, In R. Scott and S. Kosslyn (Eds), *Emerging Trends in the Social and Behavioral Sciences*, (pp. 1–11). John Wiley & Sons, 2015.
31. C. McCormick, A. R. Bielefeldt, C. W. Swan and K. G. Paterson, Assessing students' motivation to engage in sustainable engineering. *International Journal of Sustainability in Higher Education*, **16**(2), pp. 136–154, 2015.

32. C. Sevier, S. Y. Chyung, J. Callahan and C. B. Schrader, What value does service learning have on introductory engineering students' motivation and ABET program outcomes? *Journal of STEM Education: Innovations and Research*, **13**(4), pp. 55–70, 2012.
33. M. McLean, J. McBeath, T. Susko, D. Harlow and J. Bianchini, University-elementary school partnerships: Analyzing the impact of a service-learning freshman engineering course on students' engineering values and competence beliefs, *International Journal of Engineering Education*, **35**(5), pp. 1415–1424, 2019.
34. Women in Science & Engineering Leadership Institute: Project to assess climate in engineering (PACE), http://wiseli.engr.wisc.edu/pace.php Published 2009: Accessed October 2018.
35. Assessing Women and Men in Engineering: STEM assessment tools: Retention surveys: Students leaving engineering, https://www.engr.psu.edu/awe/secured/director/retention/leaving.aspx Published 2008: Accessed October 2018.
36. Assessing Women and Men in Engineering: STEM assessment tools: LAESE: Longitudinal assessment of engineering self-efficacy, https://www.engr.psu.edu/awe/secured/director/diversity/efficacy.aspx Published 2008: Accessed October 2018.
37. National Academy of Engineering Committee on Understanding the Engineering-Workforce Continuum, *Understanding the Educational and Career Pathways of Engineers*, The National Academies Press, Washington, D.C., United States, 2018.
38. National Society of Professional Engineers, *Professional Engineering Body of Knowledge*, NSPE, 2013.
39. M. Handley and C. G. P Berdanier, Operationalizing interpersonal behaviours of leadership for early-career engineers, *International Journal of Engineering Education*, **35**(3), pp. 719–732, 2019.
40. J. A. Donnell, B. A. Aller, M. P. Alley and A. A. Kedrowicz, Why industry says that engineering graduates have poor communication skills: What the literature says, *the ASEE Annual Conference and Exposition*, Vancouver, BC, Canada, June 2011.
41. P. Kompella, B. Gracia, L. LeBlanc, S. Engelmans, C. Kulkarnic, N. Desai, J. Viviana, S. March, S. Pattengale, G. Rodriguez-Rivera, S.W. Ryu, I. Strohkendl, P. Mandke and G. Clarke, Interactive youth science workshops benefit student participants and graduate student mentors, *PLoSBiol 18*(3):e3000668. 2020.
42. H. Mustafa and S. A. Freese, Impact of "Imagineer Day", an outreach program, on K-8 girls and women engineering, *the ASEE Annual Conference and Exposition*, Salt Lake City, UT, United States, June 2018.
43. M. S. Ross, T. L. Fletcher, V. Thamotharan and A. Garcia, I lead, therefore I am: The impact of student-mentor leadership opportunities on STEM identity development and sustainability, *the ASEE Annual Conference and Exposition*, Salt Lake City, UT, United States, June 2018.
44. C. Talbot, M. Alley, M. Marshall, C. Haas, S. E. Zappe and J. K. Garner, Engineering Ambassador Network: Professional development of the engineering ambassadors, *the ASEE Annual Conference and Exposition*, Atlanta, GA, United States, June 2013.
45. M. Alley, C. Haas, J. K. Garner and K. A. Thole, Engineering Ambassador Network: Progress in 2014 on creating a national network of ambassadors, *the ASEE Annual Conference and Exposition*, Seattle, WA, United States, June 2015.
46. J. S. Bates, K. J. Krapcho and C. Orantes, How to recruit and retain students using an engineering ambassador program. *the ASEE Annual Conference and Exposition*, Indianapolis, IN, United States, June 2014.
47. Z. Shabazi, A. E. Lehnes, M. A. Jacobs and K. C. Mancuso, Engineering Ambassadors: Bridging the gap between engineering and education undergraduates and middle and high school students (evaluation), *the ASEE Annual Conference and Exposition*, New Orleans, LA, United States, June 2016.
48. C. Midgley, M. L. Maehr, L. Z. Hruda, E. Anderman, L. Anderman, K. E. Freeman, M. Gheen, A. Kaplan, R. Kumar, M. J. Middleton, J. Nelson, R. Roeser and T. Urdan, *Patterns of Adaptive Learning Scales*, University of Michigan, Ann Arbor, MI, United States, 2000.
49. P. R. Pintrich and E. V. DeGroot, Motivational and self-regulated learning components of classroom academic performance, *Journal of Educational Psychology*, **82**(1), pp. 33–40, 1990.
50. A. E. Woolfolk, *Educational Psychology/LASSI User's Manual*, Allyn & Bacon, New York, NY, United States, 1996.
51. G. O. Boateng, T. B. Neilands, E. A. Frongillo, H. R. Melgar-Quinonez and S. L. Young, Best practices for developing and validating scales for health, social, and behavioral research: A primer, *Frontiers in Public Health*, **6**, pp. 1–13, 2018.
52. F. Laanan, Studying transfer students: Part 1: Instrument design and implications, *Community College Journal of Research and Practice*, **28**(4), pp. 331–351, 2010.
53. S. Metz, S. Brainard and G. Gillmore, National WEPAN pilot climate survey exploring the environment for undergraduate engineering students, *International Symposium on Technology and Society – Women and Technology: Historical, Societal, and Professional Perspectives*, New Brunswick, NJ, United States, 1999.
54. Engineering Ambassadors Network Workshop Exit Survey, Personal communication, 2018.
55. University of Nebraska Engineering Ambassadors Exit Survey, Personal communication, 2018.
56. K. Multon, Interrater reliability. In N. Salkind (Ed.), *Encyclopedia of Research Design*, SAGE Publications, Inc, Los Angeles, CA, United States, pp. 627–629, 2010.
57. A. Field, *Discovering Statistics using IBM SPSS Statistics*, Sage Publications, Ltd, Thousand Oaks, CA, United States, 2013.
58. J. Anderson and D. Gerbing. Structural equation modeling in practice: A review and recommended two-step approach, *Psychological Bulletin*, **103**(3), pp. 411–423, 1988.
59. R. Del Rey, J. A. Casas, R. Ortega-Ruiz, A. Schultze-Krumbholz, H. Schiethauer, P. Smith, F. Thompson, V. Barkoukis, H. Tzorbatzoudis, A. Brighi, A. Guarini, J. Pyzalski and P. Plichta, Structural validation and cross-cultural robustness of the European cyberbullying intervention project questionnaire, *Computer in Human Behavior*, **50**, pp. 141–147, 2015.
60. D. Hooper, J. Coughlan and M. Mullen, Structural equation modeling: Guidelines for determining model fit, *The Electronic Journal of Business Research Methods*, **6**(1), pp. 53–60, 2008.
61. D. Shi, T. Lee and A. Maydeu-Olivares, Understanding the model size effect on SEM fit indices, *Educational and Psychological Measurement*, **79**(2), pp. 310–334, 2019.
62. S. Cangur and I. Ercan, Comparison of model fit indices used in structural equation modeling under multivariate normality, *Journal of Modern Applied Statistical Methods*, **14**(1), pp. 152–167, 2015.
63. T. Anagnos, A. Lyman-Hold, C. Marin-Artieda and E. Momsen, Impact of engineering ambassador programs on student development, *Journal of STEM Education: Innovations and Research*, **15**(3), pp. 14–20, 2014.
64. P. R. Backer and R. T. Halualani, Impact of self-efficacy on interest and choice in engineering study and careers for undergraduate women engineering students, *the ASEE Annual Conference and Exposition*, Austin, TX, United States, June 2012.

65. E. D. Tate and M. C. Linn, How does identity shape the experiences of women of color engineering students? *Journal of Science Education and Technology*, **14**(5–6), pp. 483–493, 2005.
66. R. W. Lent, S. D. Brown and G. Hackett, Toward a unified social cognitive theory of career/academic interest, choice, and performance [Monograph], *Journal of Vocational Behavior*, **45**, pp. 79–122, 1994.
67. K. A. Gainor and R. W. Lent, Social cognitive expectations and racial identity attitudes in predicting the math choice intentions of Black college students, *Journal of Counseling Psychology*, **45**(4), pp. 403–413, 1998.
68. J. C. Weidman, L. DeAngelo and K. A. Bethea, Understanding student identity from a socialization perspective, *New Directions for Higher Education*, **166**, pp. 43–51, 2014.
69. A. Y. Kim, G. Sinatra and V. Seyranian, Developing a STEM identity among young women: A social identity perspective, *Review of Educational Research*, **88**(4), pp. 479–507, 2018.
70. P. J. Burke and J. E. Stets, *Identity Theory*, Oxford University Press, New York, NY, 2009.
71. H. B. Carlone and A. Johnson, Understanding the science experiences of successful women of color: Science identity as an analytic lens, *Journal of Research in Science Teaching*, **44**(8), pp. 1187–1218, 2007.
72. D. Findley-Van Nostrand and R. S. Pollenz, Evaluating psychosocial mechanisms underlying STEM persistence in undergraduates: Evidence of impact from a six-day pre-college engagement STEM academy program, *CBE Life Sciences Education*, **16**(2), 2017.
73. A. Godwin, G. Potvin, Z. Hazari and R. Lock, Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice, *Journal of Engineering Education*, **105**(2), pp. 312–340, 2016.
74. Z. Hazari, P. M. Sadler and G. Sonnert, The science identity of college students: Exploring the intersection of gender, race, ethnicity, *Journal of College Science Teaching*, **42**(5), pp. 82–91, 2013.
75. Y. Mai and S. Xao, Math and science identity changes and paths into and out of STEM: Gender and racial disparities, *Socius: Sociological Research for a Dynamic World*, **7**, pp. 1–15, 2021.
76. E. Erikson, *Youth: Change and Challenge*, Basic Books, New York, NY, 1963.
77. M. L. Maehr and L. A. Braskamp, *The Motivation Factor: A Theory of Personal Investment*, Lexington Books: D.C. Heath and Company, Lexington, MA, United States, 1986.
78. J. Marcia, Identity in Adolescence, In J. Adelson (Ed.), *Handbook of Adolescent Psychology*, Wiley, New York, NY, United States, pp. 159–187, 1980.
79. A. Wallace-Broscious, F. C. Serafica and S. H. Osipow, Adolescent career development: Relationships to self-concept and identity status, *Journal of Research on Adolescence*, **4**(1), pp. 127–149, 1994.

Appendix

Table A1. Pilot item sources and validated subscales

Item	Theorized Subscale	Validated Subscale	Source / Adapted From
AC1. I am confident I can succeed in my engineering courses.	AC	AC	Metz et. al, 1999 Lizter et al., 2014
AC2. I am confident I can succeed in my math courses.	AC	AC	Metz et. al, 1999 Lizter et al., 2014
AC3. I can complete the math requirements for most engineering majors.	AC	AC	Assessing Women and Men in Engineering (2008), LAESE.
AC4. I can complete the physics requirements for most engineering majors.	AC	Removed	Assessing Women and Men in Engineering (2008), LAESE.
AC5. I can succeed in an engineering curriculum while not having to give up participation in my outside interests (extracurricular activities, family, sports).	AC	Removed	Marra & Bogue (2006)
AC6. It is difficult to find my way around campus.	AC	Removed	Laanan (2010)
AC7. I am confident I will complete an engineering degree in my preferred major.	AC	AC	Assessing Women and Men in Engineering (2008), LAESE.
AC8. I know what to do if I am having trouble in my engineering courses.	AC	Removed	Assessing Women and Men in Engineering (2008), LAESE.
AC9. I know who to talk to if I am having trouble in my engineering courses.	AC	Removed	Assessing Women and Men in Engineering (2008), LAESE.
AC10. I am confident that engineering is the right major for me.	AC	AC	Metz et. al, (1999)
AC11. I am satisfied with my decision about my specific engineering major.	AC	AC	Assessing Women and Men in Engineering (2008), LAESE.
AC12. I am confident I will complete an engineering degree.	AC	AC	Marra et. al (2009)
ECM13. It is my choice to study engineering.	ECM	AC	Assessing Women and Men in Engineering (2008), LAESE.
ECM14. A degree in engineering will allow me to get a job where I can use my talents and creativity.	ECM	AC	Assessing Women and Men in Engineering (2008), LAESE.
ECM15. Someone like me can succeed in an engineering career.	ECM	AC	Assessing Women and Men in Engineering (2008), LAESE.

ECM16. A degree in engineering will allow me to obtain a job that I like.	ECM	AC	Assessing Women and Men in Engineering (2008), LAESE.
ECM17. A degree in engineering will allow me to obtain a well-paying job.	ECM	Removed	Marra & Bogue (2006)
ECM18. I am part of an engineering community.	ECM	Removed	Women in Science & Engineering Leadership Institute (2009)
ECM19. I am confident I will be treated fairly on the job in engineering.	ECM	Removed	Assessing Women and Men in Engineering (2008), LAESE.
ECM20. I am confident I will be given the same opportunities for pay raises and promotions as my fellow workers if I enter engineering.	ECM	Removed	Assessing Women and Men in Engineering (2008), LAESE.
ECM21. My participation as an ambassador will lead to a better understanding of engineering.	ECM	AMB	Assessing Women and Men in Engineering (2008), Retention.
ECM22. My participation as an ambassador will lead to a better understanding of my own career goals.	ECM	AMB	Assessing Women and Men in Engineering (2008), Retention.
ECM23. My participation as an ambassador will make me more confident about my ability to succeed in engineering.	ECM	AMB	Assessing Women and Men in Engineering (2008), Retention.
EB24. Engineers are creative.	EB	EB	National Academy of Engineering Committee on Public Understanding of Engineering Messages (2008)
EB25. Engineers are problem solvers.	EB	EB	National Academy of Engineering Committee on Public Understanding of Engineering Messages (2008)
EB26. Engineering is essential to our health, happiness, and safety.	EB	EB	National Academy of Engineering Committee on Public Understanding of Engineering Messages (2008)
EB27. Engineering connects science to the real world.	EB	EB	National Academy of Engineering Committee on Public Understanding of Engineering Messages (2008)
EB28. Engineers help to make the world a better place.	EB	EB	Lizter et al. (2014)
EB29. Engineers help shape the future.	EB	EB	National Academy of Engineering Committee on Public Understanding of Engineering Messages (2008)
EB30. Society values the work engineers do.	EB	Removed	Lizter et al. (2014)
EB31. Engineers make a world of difference.	EB	EB	National Academy of Engineering Committee on Public Understanding of Engineering Messages (2008)
EB32. Engineers are entrepreneurial and innovative.	EB	EB	National Academy of Engineering Committee on Public Understanding of Engineering Messages (2008)
EB33. It is important that the field of engineering is diverse.	EB	EB	University of Nebraska Exit Interview
PS34. I can apply an engineering concept or idea to a real-life situation.	PS	Removed	Marra et al. (2008)
PS35. I can weigh alternative perspectives in solving a problem.	PS	PS	Marra et al. (2008)
PS36. I can develop ways to resolve conflict and reach agreement in a group.	PS	PS	Marra et al. (2008)
PS37. If a team I am working on has a problem, I can help the team resolve the issue.	PS	PS	Assessing Women and Men in Engineering (2008), LAESE.
PS38. I can synthesize multiple points of view that arise during group problem solving.	PS	PS	Marra et al. (2008)
PS39. I can organize information so that it is easily understandable to others.	PS	PS	Marra et al. (2008)
PS40. I can communicate effectively.	PS	PS	University of Nebraska Exit Interview
PS41. I can create engaging presentations.	PS	PS	Engineering Ambassadors Network Workshop Exit Survey
PS42. I can deliver engaging outreach presentations.	PS	PS	Engineering Ambassadors Network Workshop Exit Survey
PS43. I work cooperatively with other ambassadors on our duties and tasks.	PS	PS	Marra et al. (2008)
PS44. I know how to integrate messages from "Changing the Conversation" into an outreach presentation.	PS	PS	Engineering Ambassadors Network Workshop Exit Survey

PS45. I am confident in my leadership skills.	PS	PS	University of Nebraska Exit Interview
PS46. I can provide a helpful and appropriate critique to a fellow Ambassador's presentation.	PS	PS	Engineering Ambassadors Network Workshop Exit Survey
PS47. I can select an appropriate slide design to suit the audience of my presentation.	PS	PS	Engineering Ambassadors Network Workshop Exit Survey
PS48. I can effectively be a member of a team.	PS	Removed	University of Nebraska Exit Interview
SS49. I participate in non-academic activities with other students.	SS	Removed	Laanan (2010)
SS50. At this university, I feel like I am part of a group.	SS	SS	University of Nebraska Exit Interview Laanan (2010)
SS51. If I have a problem, there is someone at this university I can talk to.	SS	SS	Assessing Women and Men in Engineering (2008), Retention.
SS52. I have a mentor to whom I can turn for advice.	SS	SS	Assessing Women and Men in Engineering (2008), Retention.
SS53. I can cope with being the only person of my race/ethnicity/gender in a class.	SS	Removed	Assessing Women and Men in Engineering (2008), LAESE.
SS54. I can make friends with people from different backgrounds and/or values.	SS	Removed	Assessing Women and Men in Engineering (2008), LAESE.
SS55. I can relate to the people around me in academic settings.	SS	SS	Marra & Bogue (2006)
SS56. It is easy for me to make friends.	SS	SS	Laanan (2010)
SS57. I believe community focus is important in what ambassadors do.	SS	Removed	University of Nebraska Exit Interview

A2. Validated measure.

Q1. We would like to be able to follow your progress through the Ambassadors program. To do this, we need to develop a code that will maintain your anonymity.

Please create a Self-Generated Identification Code (SGIC) as follows:

- What is the first letter of your mother's first name?
- How many older brothers do you have (living and deceased)?
- What is the number that represents your birth month?
- What is the first letter of your middle name? (if none, use X)

For example, the SGIC of a respondent whose mother is named Mary, who has one older brother, whose birth month is May (05), and whose middle name is Ann: M0105A

____

Q2. What college or university do you currently attend?

____

Q3. What is your gender?

○ Male (1)
○ Female (2)
○ Prefer not to respond (3)

Q4. What is your race/ethnicity?

○ African American/Black (1)
○ American Indian/Alaska Native (2)
○ Asian (3)
○ Hispanic/Latino (4)
○ Pacific Islander (5)
○ White (6)
○ Two or more races (7)
○ Prefer not to respond (9)
○ Other (please explain) (8) ____________________________

Q5. What is your current level in college?

○ Freshman (1)
○ Sophomore (2)
○ Junior (3)
○ Senior (4)
○ Other (please explain) (5) ____________________________

Q6. How many years have you served as an Ambassador?

○ This is my first year. (1)
○ This is my second year. (2)
○ This is my third year. (3)
○ This is my fourth or more year. (4)

Academic Confidence. Please indicate your level of agreement with the following statements.
Likert options: Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree.

1. I am confident I can succeed in my engineering courses.
2. I am confident I can succeed in my math courses.
3. I can complete the math requirements for most engineering majors.
4. I am confident I will complete an engineering degree in my preferred major.
5. I am confident that engineering is the right major for me.
6. I am satisfied with my decision about my specific engineering major.
7. I am confident I will complete an engineering degree.
8. It is my choice to study engineering.
9. A degree in engineering will allow me to get a job where I can use my talents and creativity.
10. Someone like me can succeed in an engineering career.
11. A degree in engineering will allow me to obtain a job that I like.

Ambassadorship. Please indicate your level of agreement with the following statements.
Likert options: Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree.

12. My participation as an ambassador will lead to a better understanding of engineering.
13. My participation as an ambassador will lead to a better understanding of my own career goals.
14. My participation as an ambassador will make me more confident about my ability to succeed in engineering.

Engineering Beliefs. Please indicate your level of agreement with the following statements.
Likert options: Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree.

15. Engineers are creative.
16. Engineers are problem solvers.
17. Engineering is essential to our health, happiness, and safety.
18. Engineering connects science to the real world.
19. Engineers help to make the world a better place.
20. Engineers help shape the future.
21. Engineers make a world of difference.
22. Engineers are entrepreneurial and innovative.
23. It is important that the field of engineering is diverse.

Professional Skills. Please indicate your level of agreement with the following statements.
Likert options: Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree.

24. I can weigh alternative perspectives in solving a problem.
25. I can develop ways to resolve conflict and reach agreement in a group.
26. If a team I am working on has a problem, I can help the team resolve the issue.
27. I can synthesize multiple points of view that arise during group problem solving.
28. I can organize information so that it is easily understandable to others.
29. I can communicate effectively.
30. I can create engaging presentations.
31. I can deliver engaging outreach presentations.
32. I work cooperatively with other ambassadors on our duties and tasks.
33. I know how to integrate messages from "Changing the Conversation" into an outreach presentation.
34. I am confident in my leadership skills.
35. I can provide a helpful and appropriate critique to a fellow Ambassador's presentation.
36. I can select an appropriate slide design to suit the audience of my presentation.

Social Supports. Please indicate your level of agreement with the following statements.
Likert options: Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree.

37. At this university, I feel like I am part of a group.
38. If I have a problem, there is someone at this university I can talk to.
39. I have a mentor to whom I can turn for advice.
40. I can relate to the people around me in academic settings.
41. It is easy for me to make friends.

Melissa G. Kuhn is an Education Specialist with The Center for Educational Partnerships and a PhD Candidate in Educational Psychology and Program Evaluation at Old Dominion University. Her research interests include validity and measurement in education research, mixed research methods, STEM education, standardized testing practices and policy, and educator identity and ethics. Ms. Kuhn also collaborates with and supports faculty at The Center for Educational Partnerships on grant-funded projects that cover a broad range of disciplines with her skills in research methodology and expertise in measure design and validation.

Shanan Chappell Moots, PhD, currently serves as Director for Research Analytics and Research Associate Professor in The Center for Educational Partnerships at Old Dominion University. She has served or is currently serving on educational research projects focusing on program evaluation, military child and family educational studies, STEM projects, measure development and validation, and college and career readiness initiatives. Dr. Chappell Moots also has an appointment as Research Fellow with the National Dropout Prevention Center and holds certifications as Dropout Prevention Specialist and Trauma Skilled Schools Specialist. She has collaborated on projects with faculty and researchers from universities and organizations across the United States and has authored or co-authored numerous peer-reviewed

journal articles and technical reports. Dr. Chappell Moots is collaborative faculty in the Educational Psychology and Program Evaluation program in the Darden College of Education and Professional Studies at ODU and teaches advanced research design and analysis in select semesters.

Joanna K. Garner, PhD is a Research Professor and the Executive Director of The Center for Educational Partnerships at Old Dominion University. Her research interests include identity development in formal and informal settings, the relations between learning and identity formation during STEM teaching and learning, and the application of complex systems theories to the design and evaluation of learning environments. She has been the principal or co-principal investigator on multiple federal, state, and foundation sponsored educational research projects and has published more than 40 journal articles and book chapters on various topics in educational research.