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The Effect of a *Caring* Intervention on Engineering Identity: Insights from a One-Day Outreach Event with Elementary and Middle School Girl Scouts*

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Women enter Science, Technology, Engineering, and Math (STEM) occupations that are commonly associated with helping and caring (e.g., health and life sciences) at much higher rates than engineering occupations. Girls interested in STEM might be unaware of the opportunities that engineering offers to help others. In this study, elementary and middle school-aged girls in the United States attended a one-day outreach event focused on environmental engineering, where they participated in hands-on activities. Participants were placed in either the caring (treatment) or control condition, where those in the caring condition heard explicit messages about engineering as a caring profession and those in the control condition did not. Before and after the outreach event, participants (n = 88) completed the Engineering Identity Development Scale (EIDS). Participants in the caring condition had higher occupational identity following the outreach event as compared to participants in the control condition (post-survey), indicating a better understanding of the engineering profession. Additionally, the engineering aspirations of middle school participants were positively impacted as compared to elementary participants. Explicit messaging about caring can help to rectify misperceptions of the engineering profession and to improve girls' understanding of engineering. Additionally, our findings suggest that such outreach events are important for the development of engineering identity in middle school girls and can encourage their engineering aspirations.

Keywords: engineering identity; caring, K-12 outreach; environmental engineering

1. Introduction

Despite decades worth of attention and effort, women remain vastly underrepresented in engineering fields at the undergraduate and graduate levels and in engineering occupations [1]. Gender gaps in science-related fields and Science, Technology, Engineering, and Mathematics (STEM) career aspirations appear as early as elementary school, despite a lack of gender differences in academic performance [2, 3]. Of particular concern is that girls tend to show less interest in STEM occupations than do boys due to cultural stereotypes and lower reported self-efficacy [4, 5]. Further, while most (70%) elementary school students express an interest in science, few (17%) are interested in science careers [2]. Contributing to the gender gap, girls interested in STEM are more likely to choose medical or healthcare professions rather than those in engineering [6]. Middle school years, defined here as ages 11–14, are a particularly important time to encourage girls' science identity development [7] because students' self-perceptions about their scientific abilities and the perceived value of science predicted interest in STEM careers for both genders [8]. Engineering is included within the national K-12 science education standards in the United States [9]; however, stand-alone national standards for engineering do not exist. Therefore, when engineering content is covered in K-12, it is most often included *within* the science or STEM curriculum. However, elementary and middle school students often lack understanding of what

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an engineering career involves [10, 11], despite the addition of engineering to the United States' Next Generation Science Standards (NGSS) in 2013. If students are exposed to the salient notion of *caring* in STEM early in their education, then this might serve as a catalyst for reducing the gender gap in science and engineering. The definition of elementary and middle school varies in the United States; in this study, we define elementary school as kindergarten to 5th grade (ages 5–11) and middle school as 6th to 8th grade (ages 11–14).

The concept of *engineering identity* encompasses both interest in and understanding of engineering as an occupation. Capobianco et al. developed and validated the Engineering Identity Development Scale (EIDS), which was designed to measure the engineering identity of elementary students (grades 1–5) [12]. Assessments, such as the EIDS, can be used to observe changes in students' engineering identities during outreach events and other learning opportunities. Interventions that introduce engineering careers to elementary students can increase their engineering identities [13], which is important as they begin to develop occupational interests. While most engineering identity research is situated in higher education, research at the elementary and middle school levels is critical to identity development during early education, as students broaden their interests and begin to consider career pathways.

Female students often are more inclined to study disciplines in which they perceive that they can help people; however, they tend to be unaware that a career in engineering can achieve this goal [14, 15]. Framing engineering as a caring and socially-engaged profession has shown to improve the perception and relatability of engineering for the general public [16] and girls in elementary school [17]. Providing engineering learning experiences designed to emphasize the concepts of caring and empathy has the potential to encourage engineering identity development in elementary and middle school girls, which might help to reduce the gender gap in engineering. Engineering outreach events, learning experiences that often are organized by engineering university instructors, students, and professionals, reach students who might have limited exposure to engineering otherwise and allow them to engage with engineering role models and activities. For example, undergraduate engineering students could attend after-school programs at local elementary schools as outreach, leading students in a focused, hour-long engineering activity where students build and test their own designs. While engineering outreach events can be conducted during school hours or in out-of-school settings, outreach that occurs in out-of-school settings has greater flexibility in design and scope as compared to that in K-8 classrooms because activities do not have to fit within required curriculum and standards.

In this study, we examine the impact of emphasizing caring as part of the engineering profession on the engineering identity of elementary (in grades 4 and 5) and middle school (in grades 6, 7, and 8) Girl Scouts during a hands-on, one-day outreach event centered around environmental engineering activities. The Girl Scouts organization is situated in the United States and designed to develop girls as leaders in their community, with a mission to "build girls of courage, confidence, and character, who make the world a better place" [18]. Girl Scouts can earn badges for their participation in a variety of activities in the focal areas of STEM, the Outdoors, Life Skills, and Entrepreneurship [19]. Both the environment and actions of caring are important to the Girl Scouts, where "environmental stewardship has been a key part of Girl Scout experience for over a century" [20] and one of the tenets of the Girl Scout Law is to "make the world a better place" [21].

2. Background

2.1 Engineering Identity in K-12 Settings

Identity can be defined as a constructed view of self that develops through participation in certain activities as well as an association with others, communities, or specific roles [22]. Research on engineering identity often draws from Gee's conception of identity, which includes the components of nature-identity, institution-identity, discourse-identity, and affinity-identity [23]. The construct of engineering identity can examine the self-perceptions of students in relation to engineering, such as how they view engineering and see themselves within the field. Engineering identity is multidimensional and consists of several interrelated components. For example, the framework used in engineering identity research in higher education measures performance/competence, interest, and recognition [24, 25] (the PCIR framework). In the current study, we have incorporated the validated three-factor model of engineering identity of Capobianco et al. [26], which was designed to measure the engineering identity development of elementary students (grades 1–5) [12]. The factors in the three-factor EIDS are as follows: (1) *academic identity* (identity related to school and academics, including performance, enjoyment, value, and sense of support), (2) *occupational identity* (understanding of the engineering profession), and (3) *engineering aspirations* (interest in the engineering profession as a future occupation) [26]. Because identity is a flexible construct that changes and evolves, the EIDS can be used to capture changes in the engineering identity factors that result from student participation in engineering-related activities and learning experiences [12]. In addition to the EIDS, several other assessments measure the development of engineering and STEM identities at the K-12 level. For example, the Draw-an-Engineer Test (DAET) assesses student perceptions and understanding of engineers [27], which is considered part of occupational identity in the three-factor engineering identity model of Capobianco et al. [26]. Additionally, the 'Is Science Me?' survey instrument and subsequent adapted versions examine science identity through social practice theory and have been used with middle school participants [8, 28].

Engineering identity research at the elementary school level has increased in recent years [29], potentially due in part to the development of the EIDS in 2012. Clark and Kajfez's review on engineering identity in K-12 [29] also found that research on middle school students was often combined with elementary or high school students, rather than a sole focus on middle school. Prior work using the EIDS shows that the inclusion of hands-on engineering lessons and curriculum in the classroom positively influences engineering identity development in elementary students [13, 26, 30]. As compared to a control group, elementary students (grades 1–5) who participated in an engineering design-based science unit showed a greater increase in engineering identity, particularly related to their understanding of engineering [30]. Similarly, elementary students (grades 2–4) had increased engineering identities after their teachers integrated engineering lessons into class, with minimal gender differences in engineering identity [13]. Initial exposure to engineering might be the most impactful for engineering identity development, as a longitudinal study using the EIDS found that elementary students' (grades 3–6) occupational identity and engineering aspirations had the greatest increase after the first of two engineering design-based science lessons were implemented [26]. The EIDS also has been used in out-of-school settings, showing that the inclusion of STEM activities in an after-school program positively influenced the engineering identity of elementary students (grades 3–5) [31]. Other factors remain influential for encouraging the engineering identity development of students. For example, prior work has shown that the discourse used by teachers, such as positioning students as engineers, can support engineering identity development of elementary students (grades 2 and 4) [32]. However, persistence and retention in engineering requires connections between students' perceived engineering identity and their personal identity and values, with female undergraduate students more likely to experience a disconnect between these as compared to their male counterparts [33].

2.2 Aspects of Care and Engineering

Individuals with communal goals, such as helping and caring for others, are less likely to be interested in STEM careers, with prevailing perceptions that STEM fields afford few opportunities to fulfill such goals [14]. High school girls interested in STEM cited *helping people* and *making a difference in this world* as their top career motivations; however, they were twice as likely to be interested in medicine/healthcare occupations than in engineering [6]. This gap persists into the workforce, where women tend to enter STEM-based occupations more commonly associated with caring and helping, such as the life (47.9%) and health sciences (69.9%), at much higher rates than they enter engineering (14.5%) [34]. Prior literature notes the appeal of caring and helping to female students within specific engineering disciplines, such as biomedical [35], environmental, civil, and industrial [36] engineering. These fields attract higher percentages of women than do other engineering disciplines, with 50.6% of environmental and 45.4% of biomedical engineering bachelor's degrees awarded to women in 2018 [37]. In contrast, only 14.2% of electrical and 14.8% of mechanical engineering bachelor's degrees were awarded to women in 2018 [37]. There has been a recent call to include aspects of caring in engineering education at the elementary level to improve girls' perceptions and understanding of engineering, particularly their occupational identity [38].

Although there is no widely accepted definition of caring within engineering education [39], Capobianco and Yu created a framework combining social responsibility and care to guide inclusion of engineering as a caring profession at the elementary level [38]. They define caring in the context of "a daily activity of caring" (p. 23), focusing on care as expressed through actions that help others. The concept of caring includes or intersects with ideas of empathy [39], communal goals [14], and social responsibility [38], and it is often discussed in the context of engineering as a helping profession. In our study, we define caring as the desire to help others and make the world a better place. In engineering education research, care is considered in topics such as humanitarian engineering and design safety as well as human-centered design, although the term *care* is not frequently used [39]. Focus on aspects of care have emerged in recent years, such as the model of empathy in engineering created by Walther et al. [40]. However, the inclusion of caring or empathy in the context of engineering remains a complex concept, as illustrated by a study where topics of empathy in STEM were poorly understood by middle school students and teachers after participating in empathy-focused STEM lessons in the classroom and during an after-school program [41].

We specifically draw from Capobianco and Yu's framework of care [38], which is grounded in four phases of care developed by Tronto [42]. As summarized by Capobianco and Yu [38] on p. 24, Tronto's four phases of care are: "(1) the caring about phase involves the recognition and realization that care is necessary; (2) the taking care of phase implies assuming responsibility for the identified need and determining how to respond to it; (3) the caregiving phase occurs when the need is met; and 4) the care-receiving phase occurs when the object of care responds to the care it receives [42]". The names of each care phase are simplified to (1) *Care about*, (2) *Taking care of*, (3) *Care giving*, and 4) *Care receiving*. Capobianco and Yu connect the care phases to the stages of the engineering design process of Atman et al. [43], to highlight how care is present within engineering [38]. In our study, we predominately focus on the *care about* and *taking care of* phases, with the inclusion of *care giving* in one of the activities. We do not include the phase of *care receiving* due to restrictions in the duration of the outreach event. Further details on the activities at the outreach event and their respective care phases are provided in later sections.

Prior work has shown that students who associate engineering with attributes such as collaboration [44] and improving quality of life [45] viewed engineering more positively or were more likely to choose engineering as a profession. Several studies have examined the impact of including aspects of care, empathy, and communal goals within engineering outreach activities targeted at middle school girls [17, 46, 47]. In one study, 5th and 6th grade girls participated in hands-on civil and environmental engineering activities during two in-class workshops, during which program facilitators led discussions on communal goals and values related to the activities (e.g., water purification in developing countries) [17]. Following the workshops, almost half of the 6th grade student participants mentioned communal goals when describing civil engineering in the post-survey. Additionally, student participants in both grades increased the number of female engineers drawn in the post-DAET and referred to the engineers as being happy in their drawings. In another study, middle school girls (6th and 8th grade) who attended an engineering summer program heard messages about empathy related to engineering and design, such as "how families are impacted by use and failure of infrastructure" (p. 6), during participation in engineering activities [47]. Besser et al. found that participants were highly empathy-oriented prior to the camp, and subsequently showed increased understanding of the connection between empathy and engineering and increased engineering career aspirations [47]. However, time constraints can make it difficult for teachers to include aspects of empathy in engineering while also teaching all steps of the design process [46]. In this study, we propose to further examine how the emphasis of care in engineering influences the engineering identity of elementary (in grades 4–5; ages 9 to 11) and middle school (in grades 6–8; ages 11 to 14) girls.

3. Research Questions

The current study was guided by two questions:

(1) In what ways is the engineering identity of elementary and middle school Girl Scouts influenced during a one-day outreach event focused on environmental engineering?
(2) Specifically, how is their engineering identity influenced in the treatment condition (i.e., *caring*, where the caring nature of environmental engineering is explicitly emphasized) as compared to the control condition (i.e., where the caring nature of environmental engineering is not explicitly emphasized)?

4. Methods

4.1 Research Setting

The outreach event took place at a campground located in the southern United States. The campground is located within a suburb of a major city and is situated about 30 miles from the center of the city. The camp, a property of the regional Girl Scout council, is a short walk from the waterfront of a nearby body of water. Residential and day camps for Girl Scouts are held at the camp during the year. The Girls Scouts is an organization in the United States for girls in K-12 grades, where they develop as leaders through participation in activities focused on STEM, the outdoors, life skills, and entrepreneurship [19]. The campground provides access to several water-based activities and amenities, including a fishing pier, sailboat center and sailing fleet, boat- and ship-watching, and canoeing. Additionally, more traditional camp amenities and activities are offered, such as a sand volleyball court, archery range, service projects, stargazing, and wildlife observation. Participants had the option to stay overnight at the camp facilities during the outreach event.

4.2 Event Context: One-day Outreach Event

Faculty, graduate and undergraduate students from the Department of Civil, Architectural, and Environmental Engineering (CAEE) at the University of Texas at Austin developed and facilitated the outreach event, where participants worked towards earning their *citizen scientist* Girl Scout badge. A nominal cost was associated with attendance at the outreach event. Our project team has a previously established relationship with the Girl Scouts; we find the out-of-classroom setting to be ideal for implementing outreach activities and that our work aligns well with the environmental stewardship of the Girl Scout organization. Our goal in hosting the outreach event was to provide exposure to the engineering profession and encourage girls' interests in engineering. Participants were Girl Scouts in grades 4–8 (defined here as ages 9 to 14), as described further in Section 4.3. The outreach event took place on one day, with the option for participants to stay overnight at the campgrounds and participate in a beach clean-up on the following day. Participants engaged in five activities during the outreach event, most of which focused on environmental science and engineering concepts related to water resources, water quality, and water treatment. The hands-on activities were designed within the general framework of problem-based learning [48]. Activities occurred over the span of four hours, with a lunch break following the first three activities. Activity descriptions are provided in Table 1 and are discussed as follows. We include the elements of engineering design present within each activity in Table 1, adapted from Table 1 (p. 29) in the study of Capobianco and Yu [38], which uses the phases of engineering design of Atman et al. [43].

One activity (*Observations*) was more generally focused on understanding the observational techniques used by scientists and engineers, and another activity (*Proclaim It!*) highlighted pollution prevention and the role of citizen scientists. The water-based activities (*Build It!*, *Model It!*, and *Measure It!*) involved multiple components, including hands-on collaboration among participants and demonstrations by the facilitators. Participants were introduced to several key concepts in environmental engineering, such as methods of water treatment (filtration), definition of a watershed, and key indicators of water quality. Participants constructed filtration devices and a three-dimensional watershed model and learned about the instruments used to measure indicators of water quality, such as turbidity, pH, and dissolved oxygen. The importance of hypothesis testing was emphasized in *Build It!* and *Measure It!*, where participants created hypotheses before data collection and analysis. They practiced data collection and analysis techniques, such as recording data in a field manual and plotting the data prior to drawing conclusions based on their findings.

Group facilitators were trained and given specific instructions on how to lead activities prior to the outreach event. One student facilitator was assigned to each group of participants, for a total of four groups. Group facilitators led the *Observations* and *Proclaim It!* activities with their assigned groups. For the remaining three activities (*Build It!*, *Model It!*, and *Measure It!*), four to five activity facilitators ran each activity, and groups cycled among the activities along with their group facilitator. Girl Scout troop leaders were present during the activities and assisted facilitators with small tasks as needed. In total, one faculty member and eighteen students from the university conducted the outreach activities.

While all groups participated in the five activities, group facilitators emphasized different aspects of engineering depending on which condition was assigned to their group. Two of the four groups were placed in the treatment (i.e., *caring*) condition, where participants heard explicit messages from their group facilitators about how engineers help others and make the world a better place. The remaining two groups, assigned to the control condition, participated in the same activities but did not receive any explicit messaging from their group facilitators related to how engineers help others and make the world a better place. Table 1 includes specific examples of discussions of caring within the context of engineering held by the caring groups for each activity and the care phase aligned with each activity, which we adapted from Table 1 (p. 29) in [38]. Discussions centered around the many ways that the environment impacts the day-to-day lives and activities of individuals. Each example was connected to the work that environmental engineers do in their jobs to protect people and the environment from harmful pollutants and to improve air and water quality of communities.

4.3 Participants

One hundred and six Girl Scouts participated in the one-day outreach event, the majority of whom completed the EIDS during survey administration while at the camp. Ninety participants responded to the pre-survey before the activities, and 88 participants responded to the post-survey after the activities, resulting in an average response rate of 84%. Each participant was a member of a Girl Scout troop, from 21 different troops within two regional Girl Scouts councils. We recruited participants for the outreach event using social media (i.e., Face-

Table 1. Outreach event activity descriptions and emphasis on caring (adapted from Table 1 in [38])

Activity	Engineering Design Elements	Description	Emphasis on Care
Observations	Problem-scoping Information gathering	• Make observations about a group of items • Learn how to create detailed descriptions of observed items	What sources of pollution do you notice in the nearby body of water? (i.e., oil tankers) How might local industry affect the water and marine organisms? *Care phase*: Care about
Build It!	Evaluation of different design options Project realization	• Use different porous materials to filter nearby water • Create and test hypotheses during filtration experiment • Learn how to log data in a field manual	What would happen if people drank dirty (e.g., non-filtered) water? How could that impact their health? *Care phase*: Taking care of, care giving
Model It!	Problem-scoping Brainstorming Idea generation	• Build 3-D watershed using modeling compound and other assorted items; observe contaminants washing into the waterbody during simulated rainfall event • Discuss sources of pollution in a watershed and pathways of pollutant transport	What happens to fish when their water becomes contaminated? (Show posters illustrating fish-kills as a result of water contamination) *Care phase*: Care about, taking care of
Measure It!	Evaluation of different design options	• Measure chlorine residual, color, suspended solids, dissolved oxygen, pH, temperature, and conductivity of nearby water • Compare with tap water collected on-site • Plot the measured water quality data in a field manual	Which water source would you want your friends to drink and why? How does measuring different indicators of the water help protect people? *Care phase*: Taking care of
Proclaim It!	Problem-scoping Idea generation	• Use plastic waste to create a collective piece of art that reads "Stop Pollution"	How would living in an area with air pollution affect you and your family? How could this impact your health or the health of others in the community? *Care phase*: Care about, taking care of

book), Girl Scout council websites, and email listservs, advertising this as an opportunity for Junior and Cadette Girl Scouts to earn their *Think Like A Citizen Scientist* badge. Juniors are in grades four and five (typically ages 9 to 11), while Cadettes are in grades six, seven, and eight (typically ages 11 to 14). Thus, the grade levels of participants ranged from fourth through eighth grade (ages 9 to 14), with a greater number of participants in the elementary grade levels. Table 2 displays participant grade level and race/ethnicity for all pre-survey and post-survey respondents. Several participants had difficulty answering the race/ethnicity questions, as indicated through the count changes between pre- and post-surveys and the high number of "Not Sure" responses. However, such a result is common with younger age groups, as they can struggle to define race [49].

Participants were assigned to four different groups, each of which was associated with the control or treatment (i.e., *caring*) condition; one group at each level in Girl Scouts was assigned to the control condition and the other was assigned to the treatment (i.e., caring) condition. We assigned the groups as follows: Sailor (Junior, caring), Diver (Junior, control), Surfer (Cadette, caring), and Swimmer (Cadette, control). All members of a particular troop at the same level in Girl Scouts (i.e., Juniors or Cadettes) were assigned to the same group. Group names align with different water-based activities because of the event's focus on water and the environment. Table 3 shows participant grade level and race/ethnicity by condition for the post-survey responses. Group-level data were not recorded for 13 participants, leading to differences in the total number of post-survey participants in Tables 2 and 3.

4.4 Survey Instrument

We used the Engineering Identity Development Scale (EIDS) [12], a 20-item survey instrument designed to measure the engineering identity development of elementary school-aged (K – 5) students, to collect data during the one-day outreach event. While initially validated as a two-factor scale through exploratory and confirmatory factor analysis [12], more recent work has validated the EIDS as a three-factor scale [26]. The two-factor model assesses academic and engineering career, and the three-factor model measures academic identity, occupational identity, and engineering aspirations. We chose to use the three-factor model in our

Table 2. Participant characteristics and demographics (pre-survey and post-survey)

Grade			**Race/ethnicity**		
	Pre-survey (n = 90)	**Post-survey (n = 88)**		**Pre-survey (n = 90)**	**Post-survey (n = 88)**
Fourth	30	29	White	58	55
Fifth	29	26	Black	3	3
Sixth	10	10	Latinx	13	13
Seventh	10	10	Multiracial	5	7
Eighth	10	10	Not sure	10	7
Not reported	1	3	Other	1	2
			Not reported	0	1

Table 3. Participant characteristics and demographics by condition (post-survey)

Grade			**Race/ethnicity**		
	Caring (n = 35)	**Control (n = 40)**		**Caring (n = 35)**	**Control (n = 40)**
Fourth	16	8	White	22	23
Fifth	7	16	Black	1	2
Sixth	4	2	Latinx	3	9
Seventh	3	7	Multiracial	3	4
Eighth	5	5	Not sure	6	1
Not reported	0	2	Other	0	1

analysis for two reasons: (1) the more recent scale validation and (2) the additional description provided by the two factors of occupational identity and engineering aspirations, as opposed to the single factor of engineering career. The survey instrument was originally designed to be a four-factor model (academic identity, school identity, occupational identity, and engineering aspirations) [12], and we believe the validated three-factor model aligns with the intentions of the original model more accurately.

Each of the three factors (academic identity, occupational identity, and engineering aspirations) consists of specific items from the EIDS, as shown in Table 4. Academic and occupational identity both contain six items, while engineering aspirations contains four items. It is important to note that occupational identity refers to students' understanding of the engineering profession, rather than their personal identification with engineering as a career. In contrast, academic identity refers to students' personal identification with academics and at school. Each item on the EIDS is measured on a three-point categorical scale, with the choices of *no* (assigned value of 1), *not sure* (assigned value of 2), and *yes* (assigned value of 3) displayed for all items. Table 4 contains the overall scale for each engineering identity factor.

4.5 Data Collection

The survey was administered during the opening ceremony and orientation (pre-survey) and during the closing ceremony (post-survey) of the outreach event, which was held in early spring 2020. The five

Table 4. EIDS instrument factors and items (developed from [26])

Factor	Scale	Specific Items
Academic identity	6 – 18	(1) I do my schoolwork as well as my classmates (5) I am good at working with others in small groups (6) I like being a student at my school (7) Being a student at my school is important to me (8) I make friends easily at my school (9) The teachers at my school want me to do well in my school work
Occupational identity	6 – 18	(10) Engineers solve problems that help people (11) Engineers work in teams (13) There is more than one type of engineer (14) Engineers use mathematics (15) Engineers use science (16) Engineers are creative
Engineering aspirations	4 – 12	(17) When I grow up, I want to be an engineer (18) When I grow up, I want to solve problems that help people (19) When I grow up, I want to design different things (20) When I grow up, I want to work on a team with engineers

activities took place between pre-survey and post-survey administration. We explained the survey to participants in detail, emphasizing that they were not required to respond to the survey and could skip any questions that they did not want to answer. Participant names were not recorded on the survey. In addition to the EIDS, we collected race/ethnicity, grade level, and group (i.e., condition) data from participants. Participants filled out paper versions of the EIDS, with an additional multiple-choice question for race/ethnicity (7 choices, including Other and Not sure) and an open-response question for grade level. Facilitators recorded group-level data (Sailor, Diver, Swimmer, or Surfer) on the paper copies as the post-surveys were collected. Group-level data were not recorded on the pre-surveys, and pre- and post-surveys were not marked with a participant ID. At both time points, participants were provided with at least 15 minutes to respond to the survey.

4.6 Data Analysis

We calculated descriptive statistics, including means and standard deviations, for the three engineering identity factors (academic identity, occupational identity, and engineering aspirations) for pre- and post-surveys overall, by grade level, and by race/ethnicity. Group-level data were not recorded for the pre-surveys, so we are unable to analyze pre-surveys by condition. Grade level was categorized as elementary (fourth and fifth grade) and middle school (sixth, seventh, and eighth grade). Race/ethnicity was categorized as White, Black, Latinx, Multiracial, Not sure, and Other. We also calculated descriptive statistics by condition and by grade level and condition for the three engineering identity factors for the post-surveys. We categorized the condition as either *caring* or *control*, dependent on assigned participant groups. The Sailor and Surfer groups were in the caring condition, while Diver and Swimmer groups were in the control condition. Pre- and post-surveys were not marked with participant ID numbers, so we do not have matched data between the two time points for subsequent statistical analyses.

To ensure scale reliability, we calculated Cronbach's alpha for each engineering identity factor as a measure of internal consistency [50]. We ran independent t-tests on the three engineering identity factors between pre- and post-surveys as a whole and by grade level. Additionally, we ran two-way analysis of variance (ANOVAs) for each engineering identity factor by grade level (elementary, middle school) and condition (caring, control) using post-survey data to determine statistical significance. We completed all data analysis using RStudio (Boston, MA). To handle missing data, we used case-wise deletion for the independent t-tests and list-wise deletion for the two-way ANOVAs, changing to list-wise due to the nature of ANOVA.

5. Results

Table 5 displays the correlations between the three EIDS engineering identity factors using post-survey responses. Academic identity is positively correlated with occupational identity ($p \leq 0.001$) and engineering aspirations ($p \leq 0.05$). Occupational identity and engineering aspirations are not correlated with each other at a statistically significant level. The values of Cronbach's alpha for each engineering identity factor, using post-survey responses, are all above the acceptable value of 0.7 [51]. All Cronbach alpha values indicate acceptable to good internal consistency (a measure of reliability) of the items for each factor.

Table 6 displays descriptive statistics, namely the pre- and post-survey means and standard deviations for each engineering identity factor, and the resulting p-values following independent t-tests on pre- and post-survey responses. The table contains information for the overall set of participants and by grade level. For the overall participants, none of the engineering identity factors had a statistically significant difference in mean value over time. For both academic and occupational identity, the means changed by less than or equal to 0.05 between the pre- and post-surveys (18-point scale). While not statistically significant, engineering aspirations ($p \leq 0.10$) increased between pre- and post-surveys for the overall set of participants.

By grade level, none of the engineering identity factors had a statistically significant difference in mean value over time. Similar to the overall dataset, the means of academic and occupational identity changed by less than or equal to 0.17 over time (18-point scale). Engineering aspirations for elementary-aged participants also had a limited change over time (+0.13, 12-point scale). While not statistically significant, engineering aspirations increased ($p = 0.103$) for participants in middle school between pre- and post-surveys.

Table 7 shows descriptive statistics for the pre- and post-survey engineering identity factors by

Table 5. Factor correlations between post-survey EIDS factors

	(1)	(2)	(3)
(1) Academic identity	1.0		
(2) Occupational identity	0.425***	1.0	
(3) Engineering aspirations	0.291**	0.176	1.0
Cronbach's alpha	0.784	0.856	0.719

*$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$.

Table 6. Independent t-tests for pre- and post-survey EIDS factors overall and by grade level

	Academic identity			**Occupational identity**			**Engineering aspirations**		
	Mean (SD)		**p-value**	**Mean (SD)**		**p-value**	**Mean (SD)**		**p-value**
	Pre-survey	**Post-survey**		**Pre-survey**	**Post-survey**		**Pre-survey**	**Post-survey**	
Overall (n = 84–87)	15.94 (2.30)	15.89 (2.71)	0.898	16.80 (1.66)	16.83 (2.19)	0.931	7.61 (2.11)	8.16 (2.14)	0.087
Elementary (n = 52–57)	15.86 (2.28)	15.81 (2.60)	0.912	16.70 (1.59)	16.69 (2.24)	0.976	7.55 (2.00)	7.68 (1.98)	0.742
Middle school (n = 28–30)	16.03 (2.38)	15.86 (3.02)	0.810	16.96 (1.81)	17.03 (2.20)	0.896	7.83 (2.27)	8.80 (2.23)	0.103

Table 7. Descriptive statistics for pre- and post-survey EIDS factors by race/ethnicity

	Academic identity		**Occupational identity**		**Engineering aspirations**	
	Mean (SD)		**Mean (SD)**		**Mean (SD)**	
	Pre-survey	**Post-survey**	**Pre-survey**	**Post-survey**	**Pre-survey**	**Post-survey**
White (n = 53–58)	16.03 (2.18)	16.06 (2.60)	16.86 (1.65)	16.98 (1.98)	7.71 (2.15)	8.20 (2.25)
Black (n = 2–3)	12.00 (5.66)	11.50 (4.95)	16.50 (0.71)	15.00 (4.36)	5.50 (0.71)	8.33 (1.53)
Latinx (n = 12–13)	16.08 (1.83)	16.08 (1.98)	16.75 (1.82)	16.85 (2.03)	7.54 (1.81)	7.58 (1.93)
Multiracial (n = 4–7)	16.00 (2.55)	15.33 (3.67)	16.25 (1.26)	16.00 (3.61)	6.80 (2.77)	8.17 (2.99)
Not sure (n = 6–10)	15.78 (2.59)	15.67 (3.67)	17.11 (1.83)	17.71 (0.76)	7.50 (1.72)	7.86 (0.38)
Other (n = 1–2)	18.00 (N/A)	17.00 (0)	14.00 (N/A)	16.50 (2.12)	12.00 (N/A)	11.00 (1.41)

race/ethnicity. While we can make only limited interpretations or statistical analyses with these data due to the small sample size of certain racial groups and the participants' difficulty in answering the race/ethnicity question, we find it important to include the information from this table because racial disparities in representation continue to persist within engineering [52]. Table 7 also highlights potential differences between varying racial and ethnic groups in baseline engineering identity and the influence of the outreach event on engineering identity development. For example, the mean occupational identity of White and Latinx participants increased over time, while occupational identity decreased for Black and Multiracial participants.

Table 8 provides post-survey descriptive statistics for the three engineering identity factors by condition (i.e., caring or control) for the participants. For each engineering identity factor, post-survey mean scores were greater for participants in the caring condition as compared to those in the control condition. The magnitude of mean difference varied by factor, as follows: academic identity (+0.69, 18-point scale), occupational identity (+1.19, 18-point scale), and engineering aspirations (+0.58, 12-point scale).

Table 9 reports post-survey descriptive statistics for the three engineering identity factors by condition and grade level of the participants. Middle school participants in the control condition had the highest mean scores for academic identity (16.29, 18-point scale), while middle school participants in the caring condition had the highest scores for occupational identity (17.91, 18-point scale) and engineering aspirations (9.17, 12-point scale). Elementary participants in the control condition had the lowest mean scores for academic identity (14.76) and engineering aspirations (7.05), while middle school participants in the control condition had the lowest scores for occupational identity (16.14). Academic identity mean scores showed limited variation by condition and grade level, with the exception of lower mean scores from elementary school participants in the control group. Occupa-

Table 8. Descriptive statistics for post-survey EIDS factors by condition

	Caring			**Control**		
Factor	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**
Academic identity	16.18	2.30	34	15.49	3.10	37
Occupational identity	17.39	1.50	33	16.20	2.70	40
Engineering aspirations	8.37	2.00	35	7.79	2.29	38

Table 9. Descriptive statistics for post-survey EIDS factors by condition and grade level

	Caring				Control			
	Elementary		Middle school		Elementary		Middle school	
Factor	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n
Academic identity	16.26 (2.30)	23	16.00 (2.41)	11	14.76 (3.00)	21	16.29 (3.24)	14
Occupational identity	17.14 (1.78)	22	17.91 (0.30)	11	16.17 (2.71)	24	16.14 (2.93)	14
Engineering aspirations	7.96 (1.64)	22	9.17 (2.44)	12	7.05 (2.03)	22	8.57 (2.34)	14

Table 10. Main effect of condition for post-survey EIDS factors

	Means				
Factor	Caring	Control	F-statistic	p-value	Effect size
Occupational identity	17.39	16.16	5.187	0.026*	0.54

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

Table 11. Main effect of grade level for post-survey EIDS factors

	Means				
Factor	Elementary	Middle school	F-statistic	p-value	Effect size
Engineering aspirations	7.51	8.85	7.354	0.0085**	0.55

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

tional identity mean scores were greater for participants in the caring condition, while engineering aspiration mean scores showed variation by both condition and grade level.

The two-way ANOVAs were run on each engineering identity factor, for a total of three two-way ANOVAs, and they included the main effects of condition and grade level. The main effect of condition was statistically significant for occupational identity (n = 71), and the main effect of grade level was statistically significant for engineering aspirations (n = 71). Interactions between condition and grade level were not statistically significant for any of the three engineering identity factors. Neither of the two main effects (condition and grade level) were statistically significant for academic identity (n = 69). Note that only participants who had both their grade and condition group recorded on the survey were included in the ANOVA for each factor.

The statistically significant main effects of condition and grade level from the two-way ANOVAs are shown in Table 10 and Table 11, respectively. The main effect of condition was statistically significant for occupational identity ($p \leq 0.05$), with participants in the caring condition having a higher occupational identity than participants in the control condition. The main effect of grade level was statistically significant for engineering aspirations ($p \leq 0.01$), with middle school participants having greater engineering aspirations than do elementary participants. The Cohen's d effect size was calculated for each statistically significant main effect, with both effect sizes categorized as medium effects [53].

6. Discussion

We examined the effect of a one-day environmental engineering outreach event on the engineering identity of Girl Scouts by using the three-factor EIDS instrument [26]. To further understand how emphasizing the role of care in the engineering profession influences engineering identity, participants were placed in one of two conditions: caring (treatment) and control. We found that participants in the caring condition had statistically significant higher occupational identity and higher, although not statistically significant, academic identity and engineering aspirations than those in the control condition following the outreach event (post-survey). There were limited changes in engineering identity over the duration of the event, except for increased engineering aspirations (p = 0.103) of middle school participants. Similarly, we discovered statistically significant higher engineering aspirations for participants in middle school as compared to elementary participants following the event (post-survey). Of the three EIDS factors, academic identity had the least significance in our findings. We also found a lack of correlation between occupational identity and engineering aspirations in the post-survey.

Our findings suggest that the engineering identity of girls is positively influenced through explicit messaging about engineering as a caring and helping profession (Table 1), particularly their understanding of the engineering profession (occupational identity). For example, during the *Build It!* activity, group facilitators assigned to the *caring* groups asked participants about the consequences to human health if people drank dirty (e.g., non-filtered) water. The role of environmental engineers in designing filtration systems for drinking water treatment was discussed, with an emphasis on how their work keeps people safe and healthy. Our study builds upon recent initiatives to include care within engineering activities for elementary-aged girls to help improve perceptions and understanding of engineering [38]. While it has been well-documented that female students interested in STEM prefer occupations more commonly perceived as being associated with caring and helping (i.e., medicine and healthcare) [6], less is known about how to effectively change the misperception that STEM careers, such as those in engineering, do not offer opportunities to help others. Several prior studies have assessed outreach events that emphasized the aspects of caring or helping in engineering (e.g., [17]); however, limited studies focus on how framing engineering as a caring profession influences engineering identity during such interventions. The use of a validated engineering identity survey instrument [12, 26] and treatment and control groups in our analysis adds needed statistical information to the growing body of literature on caring and engineering.

Occupational identity was the engineering identity factor that was most influenced by the emphasis of caring during the outreach event, as indicated by its statistical significance. While we cannot control for pre-survey responses, the post-survey differences between participants in the caring and control conditions indicates that targeted messaging during a one-day outreach event can increase girls' understanding of the engineering profession. The messaging focused on what environmental engineers do in their jobs to help others, with specific examples of how they protect human health and the environment from harmful pollutants. For example, we discussed how measuring water quality indicators allows engineers to monitor water systems and identify treatment adjustments that are needed to keep the water safe for human consumption. We speculate that occupational identity was likely impacted due to the participants in the caring condition hearing additional, detailed descriptions of engineering and engaging in conversations about how engineers help others. Our findings illustrate that thoughtful messaging can facilitate improvements in elementary and middle school girls' perceptions and understanding of an engineering career, which has important implications for reducing the gender gap in engineering. While not statistically significant, the higher academic identity and engineering aspirations for participants in the caring condition suggests that the other aspects of engineering identity might also be positively influenced by an emphasis on caring.

Our findings suggest that middle school is a particularly important time for engineering outreach events of short duration (i.e., a few hours) in encouraging engineering aspirations, which aligns with prior research highlighting middle school as a crucial period to support the science identity development of girls [7]. Middle school participants showed increased engineering aspirations ($p = 0.103$) over time (pre-survey to post-survey), unlike elementary participants, and had statistically significant higher engineering aspirations as compared to elementary participants in the post-survey. Limited engineering identity research is situated solely at the middle school level [29], and both the two- and three-factor EIDS have been validated for elementary students [12, 26]; this underscores the importance of further examining engineering identity development for middle school students in future work. An improved understanding of differences in engineering identity development at the elementary and middle school levels will help educators better design and implement appropriate outreach.

There are several possible reasons for the increased engineering aspirations of middle school participants and aspiration differences between elementary and middle school participants following the outreach event. First, the middle school participants might have more prior exposure to engineering, through outreach events and in-class science units that incorporate engineering. While most middle school students take science as a required class, science can receive less emphasis in the classroom at the elementary levels depending on their teacher and school. Second, students in middle school are more likely to seriously consider their future career than are elementary students, which could be reflected in the change and differences in aspirations. Therefore, middle school students might be more receptive to supportive interventions, such as one-day outreach events. Future work should focus on understanding how high school students respond to similar interventions. The content presented in our study could be adapted for higher grade levels by adding steps where students make design choices (i.e., choosing between different materials in a design) and navigate constraints, such as the consideration of price in the design. The activities also could involve testing and re-design of a filtration system, where high school students target meeting certain water quality specifications.

Additionally, we observed a limited change in academic and occupational identities over time (between pre- and post-surveys) for the elementary participants. This further suggests that the outreach event influenced engineering identity less for this age group. Elementary-aged participants might need additional time for the messages associated with the outreach event to sink in or to influence their developing engineering identities. This finding could also underscore the importance of appropriately scaffolding engineering outreach activities for different target age groups or levels of prior experience with engineering concepts. While not a focus in our analysis, it might be worth exploring how the presence of mentors during the activities influenced engineering identity in future studies. Additionally, the academic identity subscale showed a lack of significance in our findings, which is likely due to the Girl Scout event occurring in an out-of-school setting. Students often do not associate outside-of-school science learning, such as that in afterschool programs or summer camps, with school activities [54].

In the post-survey, the lack of correlation between occupational identity and engineering aspirations indicates that having a higher knowledge of engineering does not necessarily mean participants will have a greater interest in engineering as a future career. We viewed this lack of correlation as highly important because the goal of most outreach events is to educate, rather than persuade, students about future engineering careers. The outreach event in this study was not designed to convince participants that engineering is the correct pathway. The lack of correlation suggests that participants are making informed decisions about their careers after the event; this aligns with the intent of the outreach program, which was to meaningfully convey what environmental engineers do (and how they help others) with students who might not otherwise learn about this career. While the caring condition tended to influence understanding of engineering careers (occupational identity), engineering aspirations were more connected to participant level of schooling.

6.1 *Limitations*

We acknowledge several important limitations in our study. The primary limitation is that we cannot match pre- and post-surveys for each participant, nor can we control for condition in the pre-surveys. These limitations affect the conclusions that we can make with this existing dataset, including how the engineering identity of individual participants changes in response to the outreach event and how the incorporation of caring influences engineering identity development across the outreach event (over time). The short duration of the outreach event is another limitation, as identity is often a fluid, changing construct measured over longer time periods. An additional limitation is the use of only one instrument (the EIDS) during data collection since multiple sources of data can be collected to strengthen research design. However, our findings illustrate how identity can be impacted during one-day outreach events, which are frequently held for pre-college students, using a validated survey instrument commonly employed to measure engineering identity of these age groups. Our work should be interpreted as a pilot study that suggests the importance of emphasizing caring in developing girls' engineering identity and of the utility of such outreach events for encouraging the engineering aspirations of middle school girls. Future work should include matched participant IDs and control for condition in the pre-surveys, so that further statistical analyses can be conducted, and additional conclusions can be drawn. Additionally, because all participants were Girl Scouts who voluntarily signed up to attend a citizen science event, our findings might be specific to extracurricular events, to those already somewhat interested in STEM, or to those who enjoy being involved in organizations. The influence of caring on engineering identity development also should be explored within a mandatory school environment.

7. Conclusion

Outreach events are organized frequently by university faculty or instructors, engineering undergraduate students, and professional engineers, so it becomes important to understand how these events influence participants' engineering identity. Our findings illustrate that messaging during engineering learning activities matters and can influence engineering identity during a one-day outreach event. While women enter STEM-based professions that are more commonly associated with aspects of care and communal goals (e.g., health and life sciences) at higher rates than other STEM occupations, we show that the emphasis on care within engineering can help elementary and middle school girls better understand the engineering profession, which will allow them to make more informed career decisions. Furthermore, our work suggests the importance of targeted outreach events for middle school girls, as they begin to start thinking seriously about future careers. Future work should focus on understanding differences in engineering identity development at the elementary and middle school levels, as well as exploring how to effectively convey messages about engineering as a caring profession and training educators on such methods.

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