Journal of Pre-College Engineering Education Research (J-PEER)

Volume 12
Issue 2 *The Impact of COVID-19 on Pre-College Engineering Education*

Article 7

2022

The Impact of Girl Scout Engineering Experiences on the Identity Development of Middle Schoolers

Abigail M. Clark
Ohio Northern University, abigail.m.clark89@gmail.com

Rachel Kajfez
The Ohio State University, kajfez.2@osu.edu

The Impact of Girl Scout Engineering Experiences on the Identity Development of Middle Schoolers

Abstract

Despite years of recruitment efforts, women remain significantly underrepresented throughout engineering. While research into precollege engineering education has expanded, it has primarily focused on formal learning settings, even though students spend significantly more time outside of the classroom. The COVID-19 pandemic changed everything, including the time spent outside of the classroom in informal environments. Specifically, programs had to evolve to provide online content and at-home activities. Some programs even shut down completely. Within this context, our study sought to understand the impact of one informal engineering learning experience, a Girl Scout engineering badge, which also shifted online due to the COVID-19 pandemic. Specifically, we examined the impact on middle school girls' engineering identity development to understand how these experiences supported the development of an engineering identity. Before and after a Girl Scout engineering badge experience, 15 girls (grades 4–7) were interviewed about their knowledge and perception of engineering. The Draw-an-Engineer Test was used as a focal artifact, and we studied the girls' engineering identity through the lens of Possible Selves Theory. The engineering badge activities were facilitated online. Completely virtual and hybrid meetings were employed allowing additional insight into how outcomes differ with delivery method. Most participants showed an increase in their understanding of engineering and some developed engineering possible selves. Through our work, we noted that informal engineering experiences can improve pre-college students' understanding and perception of engineering; however, differences in program delivery, such as those caused by the pandemic, can have an impact. Therefore, significant additional research is needed to better understand the scope of the impact of informal programs particularly regarding how impacts differ across delivery modes and contexts. These discoveries can be used to shape evidence-based recommendations for impactful informal experiences.

Keywords

engineering identity, Possible Selves Theory, middle school, informal learning, girls

Document Type

Special Issue: The Impact of COVID-19 on Pre-College Engineering Education

Cover Page Footnote

This study was supported by the Battelle Engineering, Technology and Human Affairs (BETHA) endowment. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the BETHA endowment. Many thanks to the Girl Scout staff members, volunteers, troop leaders, parents, and girls who made this research possible. We would also like to thank Dr. Lindsay Burns, Dr. Renee Desing, Ms. Renee Pelan, Dr. Cassie Wallwey, and Ms. Meg West for assisting in data collection. Additional thanks to Dr. Desing and Dr. Wallwey for providing critical feedback on early drafts of this manuscript, as well as Ms. West for data quality reviews. Finally, thank you to Ms. Emma Krabbe and Mr. Gregory Mogren for their assistance in finalizing this paper.

Available online at http://docs.lib.purdue.edu/jpeer

Journal of Pre-College Engineering Education Research 12:2 (2022) 121–142

The Impact of Girl Scout Engineering Experiences on the Identity Development of Middle Schoolers

Abigail M. Clark[1] and Rachel Kajfez[2]

[1]*Ohio Northern University*
[2]*The Ohio State University*

Abstract

Despite years of recruitment efforts, women remain significantly underrepresented throughout engineering. While research into pre-college engineering education has expanded, it has primarily focused on formal learning settings, even though students spend significantly more time outside of the classroom. The COVID-19 pandemic changed everything, including the time spent outside of the classroom in informal environments. Specifically, programs had to evolve to provide online content and at-home activities. Some programs even shut down completely. Within this context, our study sought to understand the impact of one informal engineering learning experience, a Girl Scout engineering badge, which also shifted online due to the COVID-19 pandemic. Specifically, we examined the impact on middle school girls' engineering identity development to understand how these experiences supported the development of an engineering identity. Before and after a Girl Scout engineering badge experience, 15 girls (grades 4–7) were interviewed about their knowledge and perception of engineering. The Draw-an-Engineer Test was used as a focal artifact, and we studied the girls' engineering identity through the lens of Possible Selves Theory. The engineering badge activities were facilitated online. Completely virtual and hybrid meetings were employed allowing additional insight into how outcomes differ with delivery method. Most participants showed an increase in their understanding of engineering and some developed engineering possible selves. Through our work, we noted that informal engineering experiences can improve pre-college students' understanding and perception of engineering; however, differences in program delivery, such as those caused by the pandemic, can have an impact. Therefore, significant additional research is needed to better understand the scope of the impact of informal programs particularly regarding how impacts differ across delivery modes and contexts. These discoveries can be used to shape evidence-based recommendations for impactful informal experiences.

Keywords: engineering identity, Possible Selves Theory, middle school, informal learning, girls

Introduction

Engineering has been called "the most sex-segregated nonmilitary profession in the United States" (Cech et al., 2011, p. 643). While this quote is more than 10 years old, the statement remains true. There has been little significant change in the percentage of women working in engineering over the last 10 years (National Science Board, 2020). While other historically male-dominated professions are at or nearing gender parity in their graduates (e.g., Heiser, 2017; Zaretsky, 2018), the percentage of engineering degrees awarded to women has remained relatively constant and low, approximately 20% since the early 2000s (Corbett & Hill, 2015; National Science Board, 2020). The imbalanced gender composition remains despite nearly two decades of efforts focused on diversity and inclusion within engineering, which includes a focus

http://dx.doi.org/10.7771/2157-9288.1346

on women (e.g., Chubin et al., 2005; Congressional Commission on the Advancement of Women and Minorities in Science Engineering and Technology Development, 2000; President's Council of Advisors on Science and Technology, 2010, 2012; "The Research Agenda for the New Discipline," 2006). Despite focused efforts, women have remained significantly underrepresented within the field.

Through this work, we aimed to better understand how informal engineering experiences, such as those available through the Girl Scouts (*STEM—Girl Scouts*, n.d.), impact middle schoolers' engineering identity and understanding of engineering. It should be noted that this work occurred during the COVID-19 pandemic, which has also allowed insights into the impacts of hybrid and online delivery of these experiences. By understanding what role informal programs play in engineering identity development, the engineering education field can leverage these experiences to support women's increased participation in engineering.

Background

While many reasons are attributed to women's underrepresentation in engineering, research shows that the underrepresentation may begin with an early lack of understanding of the profession. In a survey of high school girls prior to their participation in an engineering outreach program offered by several universities, 82% of respondents reported that they knew little about what an engineer does, that they did not know an engineer, and that they had never considered engineering as a career for themselves (Bystydzienski et al., 2015). If we are to improve women's representation within the engineering field, girls must first understand engineering enough to consider it as a future career.

Though many interventions have targeted high school students (e.g., Bystydzienski et al., 2015; Cantrell & Ewing-Taylor, 2009; Holmes et al., 2012; Monaco et al., 2016), middle school or earlier may be a more beneficial point at which to intervene to develop a fundamental understanding of engineering. Career development research has shown that students begin to eliminate careers as possibilities for themselves as early as nine years old, based on their perceptions of their ability and the perceived prestige of the career (Auger et al., 2005). Additionally, there is often a large drop in math interest and perceived ability (Muzzatti & Agnoli, 2007; Steffens et al., 2010) as well as science interest (Carlone et al., 2014; Vedder-Weiss & Fortus, 2011) for both girls and boys during middle school. This drop, especially in math interest and perceived ability, is more predominant in girls than it is in boys (Muzzatti & Agnoli, 2007). Finally, research has shown that students who expect to have a science, technology, engineering, and math (STEM) career in middle school are more likely than their peers to earn a science or engineering degree (Tai et al., 2006), and students who have been exposed to engineering design activity are more likely to see themselves as potential future engineers (Douglas et al., 2014). Combining these factors highlights the importance of introducing engineering in middle school or earlier to increase women's participation.

To help close the gender gap in engineering, a variety of engineering opportunities must be made available to middle school girls, such as experiences in school, at home, and in the community, to increase girls' exposure to the field in many aspects of their lives. However, there is also a critical gap in understanding how engineering education occurs outside of the classroom and its impact. Much of the research that has been conducted in pre-college engineering education has focused on formal classes and classroom activities (Hynes et al., 2017). In a literature review of more than 200 articles on P-12 engineering education (which is engineering education experiences that occur from preschool through twelfth grade) about 75% of the articles focused on in-class experiences. However, pre-college students only spend about 20% of their time in the classroom (National Research Council [NRC], 2015), meaning that large swathes of time, where students may be introduced to engineering, have remained unstudied. The NRC (2015) found that STEM out-of-school programs can support students' knowledge of and interest in STEM. Therefore, a better understanding of the experiences outside of the classroom will allow these experiences to be leveraged in supporting developing girls' interest in engineering.

Despite the lack of research on informal learning experiences, a wide range of informal STEM opportunities exist, in what the NRC (2015) calls the "STEM learning ecosystem." The STEM learning ecosystem consists of designed settings, such as clubs, museums, and youth organizations (including our setting, the Girl Scouts), as well as naturalistic settings, people and networks of people, and everyday encounters. Youth organizations comprise approximately 8% of informal STEM programs (Laursen et al., 2013). The STEM programs offered by these organizations leverage hands-on activities to engage participants in STEM learning (e.g., Girl Scouts of the USA, 2018a), which are often unassessed and not researched. Little research has been done to deeply understand the impact of these youth organizations, though some studies (e.g., Kleinfeld & Shinkwin, 1983; Paulsen et al., 2015) have identified these organizations as effective ways for P-12 students to engage with STEM.

While there is limited research on informal engineering experiences specifically, informal STEM education for K-12 has been more widely studied. For example, the National Science Foundation has the Advancing Informal STEM Learning (AISL) program (AISL, n.d.). Research regarding informal STEM education programs often shows positive outcomes for their participants. For example, a study of girls engaged in an after-school science club showed an improved understanding of science in their everyday life and an increased science identity (Gonsalves et al., 2013). Similarly, a multi-year study of girls participating in an after-school technology club found that engagement in the club supports their STEM growth and understanding (Hug & Eyerman, 2021). Programs outside of after-school contexts have also shown positive impacts on their participants. For example, Kekelis (2017) studied a long-term program offered by a science center, where girls participated in design-based activities, and found that approximately 60% of participants could see themselves working in STEM. Additionally, STEM-related summer camps have been effective sites for pre-college students to explore and gain interest in engineering and other STEM fields. For example, a study by Chapman and colleagues (2020) found that a STEM summer camp was an effective tool to teach Hispanic girls about STEM topics, as they showed significant gains in content knowledge. Even more recently, a survey of STEM outreach indicated that, even during the COVID-19 pandemic, STEM outreach has continued and has undergone a transformation that may improve access to engineering for many students (Ufnar et al., 2021). While this insight into informal STEM provides promise for informal engineering education, if we are to address long-standing underrepresentation in engineering, it is critical to focus on engineering specifically.

Our study begins to fill the gap in research on informal pre-college learning by focusing on the impact of engineering experiences on middle school girls through their participation in a Girl Scout badge. This impact was investigated through the identity framework of Possible Selves Theory (PST) (Markus & Nurius, 1986). Understanding how exposure to engineering influenced how girls viewed engineering in relation to their possible selves (i.e., their identity) may help better support the development of future engineering professionals.

Theoretical Framework

Identity research, which is often based on the initial work of Erikson (1968), seeks to understand how people view themselves. Despite a similar starting point, identity is now defined in many ways, including the answer to the question "Who are you?" (Vignoles et al., 2011) or "the 'kind of person' one is seeking to be and enact in the here and now" (Gee, 2000, p. 99). Additionally, identity can be examined as defining who someone sees themselves becoming through frameworks such as PST (Markus & Nurius, 1986) and Future Time Perspective (Nuttin, 1964). These, along with other frameworks, focus on investigating the self (i.e., an individual's personal views on their identity). In addition to how individuals view themselves, identity research has also examined identity within groups (Ashforth & Mael, 1989), such as nationalities (e.g., Schildkraut, 2007), family groups (e.g., Felix, 2018; Quintelier et al., 2014), and careers (e.g., Hatmaker, 2013; Jue & Ha, 2018; Kettler et al., 2017; Vieira et al., 2017). How people identify with careers is often of particular interest to engineering education researchers (e.g., Buontempo et al., 2017; Capobianco et al., 2015; Douglas et al., 2014; Godwin et al., 2015), as researchers seek to understand students' paths to and through college engineering programs and into the engineering profession.

Specifically, in engineering education, identity research is blossoming (Morelock, 2017; Patrick & Borrego, 2016); however, much of the research regarding engineering identity has been focused on undergraduate engineering students (Morelock, 2017). While the body of identity research focused on pre-college students is relatively small, the studies show increases in engineering identity following exposure to a variety of engineering design activities (Clark & Kajfez, 2019). For example, in a study of elementary school children, Capobianco and colleagues (2015) found that exposure to hands-on engineering activities led to an increase in engineering identity, as measured by the Engineering Identity Development Scale (Capobianco et al., 2012). Similarly, Hughes et al. (2013) found that middle school girls who participated in a STEM camp showed a greater impact, overall, on their STEM identity than their male peers. Additionally, previous research has indicated that an engineering identity is a key element in recruitment and retention in engineering (e.g., Beam et al., 2009; Matusovich et al., 2010). Given the apparent efficacy of pre-college engineering activities and the importance of identity to students continuing to pursue engineering, it is critical to understand how engineering identity develops in a range of pre-college settings.

Because our research is focused on middle school students who are still developing career goals and plans for their future, we framed identity using PST, which was developed by Markus and Nurius (1986). Research using PST explores how individuals picture themselves in the future, based on who they perceive themselves to be in the present and who they have been in the past. Oyserman and Markus (1990a) characterized possible selves as three types: hoped-for selves, expected selves, and feared selves. Hoped-for possible selves are who someone wishes to become, even if a lofty goal, such as becoming a famous actor or a professional athlete (Oyserman & Markus, 1990a). However, if an individual views these hoped-for selves as an attainable goal, they can become expected selves and form the basis for goal setting and plan development (Oyserman & Markus, 1990b). Those possible selves which people do not wish to become are called feared selves. Feared selves can also act as motivators, as individuals seek to avoid becoming their feared possible selves

http://dx.doi.org/10.7771/2157-9288.1346

(Markus & Nurius, 1986; Oyserman & Markus, 1990b). Understanding all three selves is important as it provides insight into how students view engineering in relation to their future.

While many theories could have been used to frame this research, PST is well situated for our work as it has been widely used to study middle and high school students' views of their future selves in a variety of contexts. Lips (2004) investigated how possible selves differed between male and female high school students. That study concluded that female students showed less identification with traditionally masculine disciplines, including STEM fields. This further illustrates the need to support the exploration of engineering as a possible self for girls before high school, if the gender gap in engineering is to be closed. Further supporting this need, studies highlight the importance of possible selves for goal setting and achievement for middle school students (Oyserman et al., 2004, 2006). Providing the opportunity for girls to explore engineering and supporting the development of engineering as a realistic possible self may help close the persistent gender gap in the engineering field. Our study used PST to provide insight into how completing the Cadette Girl Scout Programming Robots (Girl Scouts of the USA, 2018b) badge impacted how girls view engineering in relation to their possible selves. While the information made publicly available by the Girl Scouts does not specifically indicate that this badge was intended to impact identity, it is consistent with their stated goals of bringing more women into the STEM field (Girl Scouts of the USA, n.d.) and takes a similar approach to other informal programs in using exposure to engineering activities as a mechanism to increase engineering identity (e.g., Douglas et al., 2014).

By investigating engineering identity development through the lens of PST, we can gain insight into how informal learning experiences impact participants' views of engineering and how it fits within their various imagined possible selves. Understanding these impacts may allow us to leverage a wide range of informal experiences to support the development of engineering as an expected possible self in young women, who have been traditionally underrepresented in engineering. Otherwise, engineering is likely to remain an unconsidered possible self for many young women.

Methods

This study included two phases, a pilot phase and a full phase, that both occurred in the context of a Girl Scout engineering badge. Girl Scout badges are awards that are available for Girl Scouts to earn by completing a series of requirements as they learn new skills and explore areas of interest. The requirements to earn these are set forth by the Girl Scouts of the USA and vary based on age level and badge topic (*Award and Badge Explorer*, n.d.). While there is a patch associated with completing these requirements, we use "badge" and "badge workshop" to refer to the activities that were completed, as this is common language within many Girl Scout troops. Pre- and post-interviews were conducted with middle school girls before and after the engineering badge. In this study, we sought to answer the questions:

- *How does the completion of the Cadette Girl Scout Programming Robots badge affect middle school girls' views of themselves as future engineers?*
- *In what ways, if any, does the completion of the Cadette Girl Scout Programming Robots badge affect middle school girls' ability to describe key components of engineering work?*

Participants

Participants for this study were recruited through a multiple-phased approach following IRB-approved procedures. First, we attended the Girl Scout service unit meeting for the region and presented the research project asking for volunteers. We initially received responses from seven troops from which the participating troops were selected. Of the seven troops that expressed interest, three were Brownie (Grades 2–3) or Daisy (Grades K-1) troops. However, since we were focused on middle school students, only troops who expressed interest and met the middle school age criteria were selected. While we would have liked to recruit more troops, the beginning of the COVID-19 pandemic prevented further recruitment activity.

Two troops participated in the pilot and two participated in the full study. The two troops which participated in the pilot study were Cadette troops (Grades 6–8), whereas both troops in the full study were multi-aged troops which included Junior and Cadette Girl Scouts (Grades 4–8). While this is a slight misalignment between the pilot and the full study, piloting with older girls proved to be useful in terms of smoothing out processes and approaches to this work. All troops were in a suburb of a large Midwestern city. Once troop leaders agreed to participate in the study, we attended troop meetings, where we met with parents and presented the research again.

Girl Scout troop members were not required to participate in the research study to take part in the badge workshop, though most troop members ultimately chose to participate in the study. Following IRB-approved procedures, parents were asked to give written permission for their child to participate in the study before the interviews, and participants gave verbal assent during the interviews. All interviews and badge workshops were attended by two members of the research team in accordance with institutional policies regarding working with minors. The research team consisted of the lead author and several graduate students who were trained on the research protocols and working with minors.

The study was initially planned to occur in person; however, we transitioned to a virtual setting for the pilot study prior to data collection due to the COVID-19 pandemic. Therefore, in addition to piloting the interview protocols, the pilot study was used to adjust the badge content to ensure it could be delivered virtually and to ensure the research design would translate into a virtual environment. Due to the continuing pandemic, the full study also occurred virtually.

Badge Activities

The two troops in the full study selected Programming Robots, a Cadette-level badge, which is the first in a series of robotics badges. To earn the badge per the Girl Scout badge requirements, the girls were required to:

1. Learn about the parts of a robot: Participants were introduced to categories of robot parts (sensor, effector, controller, actuator, and housing), each of which were defined by the Girl Scout badge material. They then played a card game to "build" robots to accomplish a specific task using the parts that they had in their hand.
2. Build a simple sensor: Participants used copper tape, a watch battery, scotch tape, and an LED to build a sensor on an index card. The LED on the sensor activated when pressure was applied to a fold in the card, thus acting as a rudimentary pressure sensor.
3. Make a box model of a robot: Participants used a cardboard box to prototype the implementation of the pressure sensor on their robot. Many participants implemented the sensor as a collision sensor, where the light would turn on if the robot ran into something.
4. Learn about programming: Participants learned about how to write an algorithm. They then wrote an algorithm for a basic household task.
5. Write a program for a robot: Participants wrote pseudocode for a robot to vacuum a room, focusing on creating an algorithm that can be used as the room is rearranged or if the robot moves to a new location.

These activities took place over two 90-minute-long meetings with each troop with steps 1–3 occurring at meeting one and steps 4 and 5 occurring at meeting two. One researcher led the activities and made every effort to present the badge material as prescribed by the leader's guide which is not publicly accessible (i.e., it must be accessed through the Girl Scouts). This allowed us to investigate the impact of this intervention and ensure consistency of presentation between the two troops. A second member of the research team attended the meetings to act as a second adult and backup facilitator in case of technological challenges. Throughout these activities, the work of engineers was discussed as it related to the badge activity. However, in efforts to limit our influence on the participant's experience, the descriptions of engineering within these contexts were limited to what was noted in the leader guide. Completion of the activities earned the girls the Programming Robots badge which were distributed by the leaders at their discretion (e.g., some troops distribute at a regular meeting while others have a special ceremony).

The Girl Scout Programming Robots badge is intended to be done with a group of participants in an in-person setting. Activities are a mix of large-group activities (step 1), individual activities (steps 2, 4, and 5), as well as smaller-group activities (step 3). While every effort was made to replicate the activities in the leader's guide when the study moved into a virtual environment, changes had to be made. Most activities remained substantively the same but were led remotely by the research team. Step 5 (writing a program for a robot) required the most changes to work in the virtual environment. These changes were informed by the participant outcomes and observations made during the pilot study. For the activities that changed, we first identified the learning objective. We then adjusted the activity to work for the virtual environment but still achieve the learning objective. For example, one activity asked participants to write an algorithm for a robot vacuum to navigate a "room," which was to be set up on a chessboard, so that it could be quickly and easily altered. However, in the pilot study, this did not translate well to a virtual environment, as setting up the "room" added confusion and distracted from the purpose of the activity which was to develop an algorithm. Therefore, in the full study, we provided an apartment floor plan as the "room" for the robot vacuum to navigate. While this "room" could not be altered like the original activity by moving to a static floorplan, participants could focus on the purpose of the activity: developing and testing their algorithm.

Due to the COVID-19 pandemic, all interactions between the participants and the research team occurred via Zoom, an online video-conferencing platform. One troop, now referred to as "the hybrid troop" in the remaining sections of this paper, gathered in person with the research team joining via Zoom, whereas the other troop, now referred to as "the online troop" in the remaining sections of this paper, met completely online. A total of 15 Girl Scouts, nine from the hybrid troop and six from the online troop, participated in the study as shown in Table 1. It should be noted that 11 of the 15 participants were Cadette Girl Scouts (Grades 6–8) and the remaining participants were Junior Girl Scouts (Grades 4–5).

http://dx.doi.org/10.7771/2157-9288.1346

Table 1
Study participants.

Pseudonym	Age	Grade	Race	Meetings attended	Troop	Connection to other participants
Addison	12	6	White	1[a]	Online	
Aubrey	11	6	White	1 and 2	Online	Lily's sister
Ava	11	6	Prefer not to respond	1	Hybrid	Interviewed in same session as Grace
Avery	12	6	White	1	Hybrid	
Chloe	10	4	White	1	Hybrid	Ella's sister
Elizabeth	11	6	White	1 and 2	Hybrid	
Ella	12	7	White	1	Hybrid	Chloe's sister
Evelyn	12	6	White	1 and 2	Hybrid	
Grace	12	7	White, American Indian or Alaskan Native	1	Hybrid	Interviewed in same session as Ava
Hannah	10	5	White	1 and 2	Online	
Harper	11	6	White	1 and 2	Hybrid	
Mia	12	6	White	1 and 2	Hybrid	
Lily	10	5	White	1 and 2	Online	Aubrey's sister
Victoria	11	6	White	1 and 2	Online	
Zoey	11	5	White	1 and 2	Online	

[a]Addison's mother asked for the leader's recording of the activities for the second meeting, but Addison did not attend the meeting live.

As discussed below, this study employed interpretative phenomenological analysis (IPA) for data analysis, which was developed by Smith et al. (2009). The number of participants recruited for this study was chosen based on the recommendations for this analysis method. Vagle (2018) suggests adjusting the number of participants based on the amount of time that is able to be spent and phenomenological data that is able to be collected and recommends recruiting ten to fifteen participants where less data is to be collected. Additionally, Smith et al. (2009) recommend three to fifteen participants for IPA studies. As such, our 15 participants fell within this recommended IPA range.

Data Collection

Participants' initial understanding of engineers and engineering was collected via the Draw-an-Engineer Test (DAET) (Knight & Cunningham, 2004). The DAET asks participants to draw an engineer at work and to write a short explanation of what an engineer does. Participants were given 15 minutes to complete their drawing and short response. Following the completion of the drawing, a short interview lasting approximately 15–20 minutes was conducted. The interview focused on the participant's interpretation of their drawing but also included questions regarding the participant's views of themselves in the future. The interview questions were developed from previous PST research (e.g., Oyserman & Markus, 1990b) and the DAET (e.g., Mena et al., 2009). The interviews were semi-structured in nature to allow for additional probing questions to be asked as needed (Lichtman, 2013). The interview protocol can be found in the appendix.

Following the completion of the badge, the participants again completed the DAET, combined with a second short interview. The second DAET was a variation on the DAET developed by Knight and Cunningham (2004), and the participants were asked to draw themselves as an engineer. This variation provided insight into how the participants view engineering in relation to their possible selves by asking them to envision themselves as an engineer in the future. As with the pre-interviews, the interview protocol can be found in the appendix.

Analysis

Since this study seeks to understand the meaning that participants make of the badge experience (i.e., how this experience influences how they think about themselves as future engineers), we employed IPA (Smith et al., 2009). While many schools of phenomenology focus on understanding the experience itself, IPA focuses on understanding the meaning that participants make of a life experience, in this case, exposure to engineering through a Girl Scout engineering badge. Figure 1 shows how interviews were analyzed.

To begin the analysis, the interviews were audio-recorded and transcribed by a professional transcription service. During this transcription, some filler words (e.g., umm) were removed to improve understandability while the rest of the girls' dialogs were maintained. Next, the transcribed interviews were checked for accuracy and de-identified. Then, the interviews were uploaded to Dedoose, a mixed-methods analysis software, for coding. A codebook was initially developed during the pilot study to help identify the critical elements of the interviews. The iterative process of developing the codebook began by identifying *a priori* codes from PST. These *a priori* codes included expected possible self, feared possible self, and

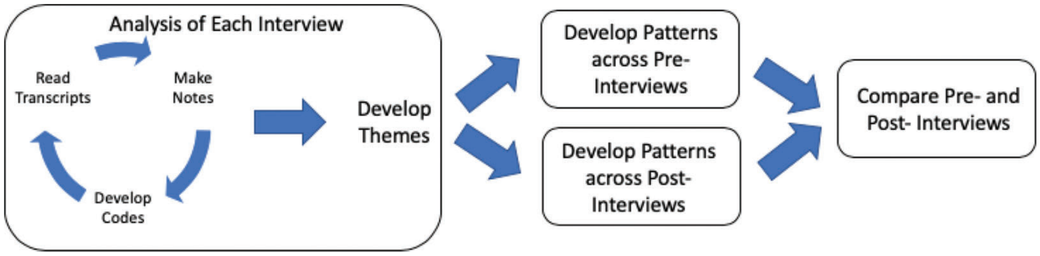

Figure 1. Interview analysis approach (Smith et al., 2009).

hoped-for possible self. As we read the interviews, additional codes, such as previous experiences with engineering, were developed to follow the patterns in the interviews and to allow the data to guide the analysis.

Each interview was read and coded independently, making notes about each interview along the way, and continuing to update the codebook to best reflect the data set. Once all the interviews had been read and coded with the same codebook, a second researcher coded two participants' pre- and post-interviews (a total of four interviews) independently as a quality check. These coded interviews were compared to initially coded interviews and any differences were resolved through discussion until a consensus was reached. The codebook was updated based on these conversations and the changes made were propagated to other interviews to ensure that codes were being applied consistently across the body of interviews.

Following the coding, a structured memo was developed for each participant. The goal of this memo was to highlight the most important elements of each interview and was structured based on the work of Wallwey et al. (2020) and Lee et al. (2019). To develop the memo, we read each coded interview and the notes about that interview to develop a summary of that interview, including salient quotes, examples, and their DAET images. Additionally, a summary of the participant's possible selves and views of engineering, as expressed in the interview, was included in the memo. Each participant's memo had a separate section for the pre- and post-interviews. As with the interview coding, after the memos were complete, a second researcher reviewed two participants' memos along with the participant's interviews to ensure that they were representative of the interviews. Following a discussion regarding the suggestions from the second researcher, the whole body of memos was updated in response to improve accuracy and consistency across memos.

Each memo and associated interviews were then reviewed to develop themes. Smith et al. (2009) describe the development of themes as, "An attempt to produce a concise and pithy statement of what was important in the various comments attached to a piece of transcript" (p. 92). As they were identified, themes were compiled into a table, along with quotes or summaries of portions of the interview which supported the themes. While themes were being developed, patterns begin to emerge. As patterns emerged, they were refined by reviewing the memos again and returning to the coded interviews, as needed, for evidence such as direct quotes, summaries of longer sections of dialogue, or DAET images. This process was repeated for the post-interviews until the pre- and post-interviews each had their patterns across participants. Next, the pre- and post-interview patterns were compared to investigate how participants changed across the engineering badge experience.

Finally, to understand how the participants' understanding of engineering differed between the pre- and post-interviews, the interviews were reviewed for an understanding of engineering. To conceptualize "understanding," we drew on the definition of engineering and engineering design from the Next Generation Science Standards (NGSS) (2013). According to NGSS, engineering and engineering design are comprised of three components:

1. Defining and delimiting engineering problems.
2. Designing solutions to engineering problems.
3. Optimizing the design solution.

Grade-level standards are provided for each of these components; however, since the interview protocol was not developed to investigate the nuances of the NGSS framework, this analysis focused on the presence or absence of each of these components, rather than trying to place a participant at a particular grade level with accompanying standards. The grade-level standards were used to operationalize each of the three components. Some examples of this operationalization can be seen in Table 2.

Each interview was then read again focusing on the portions of the interview where the participant was describing engineers and engineering. These descriptions were compared against the NGSS engineering components to identify instances where the participant included engineering components within their descriptions. Additionally, these descriptions of engineers and engineering were compared to "stereotypical" descriptions of engineering, such as a mechanic or technician. These engineering stereotypes were developed from previous work in the DAET (e.g., Carr et al., 2012; Fralick et al., 2009).

Table 2
Operationalizing NGSS engineering components.

Component	Standard examples from NGSS
Define	Identifying problems that can be solved through engineering, specifying criteria and constraints
Design	Convey solutions through visual or physical representation, explore multiple possible solutions
Optimizing	Compare solutions, test, and evaluate solutions, improve solutions based on test results, iteratively test, and refine designs

Research Positionality

Both authors have been involved with Girl Scouts in a variety of capacities for many years. This includes time as a girl member, a summer camp counselor, and, for the lead author, a program volunteer in both outdoor and STEM programs as an adult. While this background lends a great deal of institutional knowledge of the organization and helped us make the contacts needed to facilitate this study, it also brings potential bias. For example, we both have had very positive experiences with the organization which may not represent all experiences. This could have clouded our views of the data during interpretation.

Additionally, we are women in engineering, and our experiences in the engineering field led us to have a vested interest in improving women's representation in engineering. This brings passion to this project, but again, the potential for bias and influence over the results. Specifically, the first author was a facilitator for the activities, and she purposefully bracketed her engineering experience by not discussing it in detail with the girls. While this mitigated the impact as further explained in the limitations section below, our experiences could have induced bias that impacted the interpretation of the results and the participants' data.

Finally, while youth-serving organizations, such as Girl Scouts, typically have fewer leaders with STEM backgrounds than in other informal settings (Laursen et al., 2013), we are both engineers as were the other researchers who assisted in data collection. While we attempted to adhere as closely as possible to the badge's leader guide and limit our discussion of our own engineering experiences, there is a possibility that our presence served as engineering role models (e.g., NRC, 2015) for the participants and may have played some role in how they view themselves in relation to engineering. The NRC (2015) identifies role models as a key element of the STEM learning ecosystem and that these role models can serve as an encouragement to participants in STEM interest and pursuits, particularly for participants who may not see themselves as someone interested in pursuing participation in STEM fields. This role model effect may mean that participants were more impacted by the badge experience than they may have been in the circumstance where troop leaders led the activities.

We sought to mitigate these biases by employing high-quality research approaches to develop interview protocols and conduct our data analysis. For example, each round of analysis included quality checks by other experienced researchers (all of whom held an engineering and/or education degree, were not directly part of this research project, were not all former Girl Scouts, and were not all women) outside of the authorship team to ensure that the data supported the conclusions. While all biases and their impact could not be removed, especially those induced by the extensive engineering experience on the team, steps were taken to lessen their impact.

Limitations

Outside of bias implications, there are several limitations to this study. First, this study occurred over a relatively short window of time, approximately four to six weeks between pre- and post-interviews. Identity development is an ongoing process, especially through adolescence (Erikson, 1968), so a longer period of study may provide better insight into the impacts of these experiences. Within the context of this study, this may mean that with more time the impacts of the badge experience may change. For some, while there seems to be limited or no impact now, the experience may later be identified as an important turning point. However, this long-term impact cannot be obtained from this data set and would require additional study.

Second, our participant population was nearly all white, as shown in Table 1. Ideally, we would have liked to have a more diverse population; however, we were limited by the memberships of troops who expressed interest in the study, and we did not screen for troop demographics in the initial recruitment. While a homogenous population is suggested by Smith et al. (2009) for IPA work, the lack of diversity also limits insight into how other identity factors, such as race, impact participants' engineering identity development.

Finally, the modifications made to the badge activities in response to the need to move online due to the COVID-19 pandemic may also have impacted the participants' engagement with the material, either positively or negatively. Because of the timing of the work, we do not have data regarding the implementation of these badge activities in a face-to-face environment to compare against.

Results

In this section, the results are sorted into two overarching areas of analysis: participants' possible selves and understanding of engineering. Both are explored below using findings from the research.

Engineering as a Possible Self

While participants in both troops generally did not hold engineering possible selves during the pre-interview, following the completion of the Programming Robots badge, there was a difference between participants from the online troop and participants from the hybrid troop regarding the development of engineering possible selves. Participants from the online troop were more likely to show signs of a developing engineering possible self than the participants in the hybrid troop. The participants in the hybrid troop typically maintained their initial perception of engineering as not being part of their pool of possible selves. While these differences seemed to emerge, as discussed below, other factors beyond the delivery mode such as the level of engagement with the material may have been an influence.

Pre-Interviews

During the pre-interviews, ten of fifteen participants expressed that they viewed engineering as incompatible with who they are or their goals in life. Generally, these views were sorted into two categories: they did not have the correct skills or knowledge to be engineers, or they simply had no interest in engineering (or what they perceive to be engineering). Many of the participants held views of engineering related to being a mechanic or technician, so these perceptions of engineering likely influenced how they viewed engineering.

Four of the participants (Elizabeth, Chloe, Victoria, and Ava) said that they did not see themselves becoming engineers because they did not believe that they had the appropriate skills to be an engineer. Three of these participants, Elizabeth, Chloe, and Victoria, all attributed this to poor math abilities. For example, while discussing what engineers need to know to do their jobs, Chloe said "[Engineers need to know]…math, science, and maybe lots of other things. You need to learn tech…I'm not very good at math." It is interesting to note that several other participants (Avery, Evelyn, and Harper) said that they too had poor math abilities, but neither Avery, Evelyn, nor Harper related math to engineering at this point.

Six participants (Harper, Grace, Evelyn, Lily, Addison, and Aubrey) expressed that they had no interest in engineering or what they perceived engineering to be for a variety of reasons. For example, Grace's perception of engineering had been influenced by her career exploration class. Grace said, "I'm taking a career explorers class, so I get to take these different tests and seeing what I'm doing and literally engineering's on the bottom." Addison and Aubrey were uninterested in engineering because of the tasks they believed engineers performed.

The other five participants (Hannah, Avery, Mia, Ella, and Zoey) indicated some interest in engineering. However, it seems that only Ella, Hannah, and Zoey had a possible self that is an engineer. For example, when asked how she would feel if she found out she had become an engineer, Ella said, "I would feel really good…because it was one of my dreams." Hannah, Ella, and Zoey all seem to have considered how engineering fits into who they are now and who they see themselves becoming, and thus have developed a possible self related to engineering prior to the badge activities. By comparison, Avery expressed interest in some aspects of engineering, particularly sketching things out, and Mia said that she would be excited to learn she was an engineer because she has a job. However, neither Avery nor Mia showed any signs of having considered how engineering fits into who they are becoming, so while some interest may have existed prior to the Programming Robots badge, it does not appear that this interest informed any views of themselves in the future.

Overall, most participants started the study with possible selves completely unrelated to engineering. Ella, Zoey, and Hannah seemed to have possible selves related to engineering, but none of the other twelve participants did. Almost across the board, participants described expected and hoped-for possible selves related to their current interests and hobbies, such as horseback riding or crafts.

Post-Interviews

When comparing the two troops before the badge workshops, the two troops were relatively similar but differences emerged in the post-interviews. The participants in the online troop seemed to be more likely to have developed a possible self related to engineering than the hybrid troop.

Within the online troop, four participants (Hannah, Zoey, Aubrey, and Lily) indicated that they could envision themselves pursuing engineering in the future. As seen in the pre-interviews, Hannah and Zoey had already developed an engineering possible self before the badge experience. However, Aubrey and Lily had not initially had possible selves related to engineering and viewed engineering as not interesting to them. In her post-interview when asked about becoming an engineer in the future, Lily said, "I think [programming is] really interesting and it's one of the few things that I'm good at…because it's something I enjoy and I think would be fun to do again." Both Lily and Aubrey attributed this change in perception to an improved understanding of engineering, having not realized that robotics and programming could be part of engineering. Aubrey said, "I didn't know that [programming was part of engineering] before you told us and taught us about it. So I just thought that engineering was working with engines. And then the second time I drew [the DAET], I knew that it could be programming." It is interesting to note that, as shown in Table 1, Lily and Aubrey are sisters. It is possible that their existing relationship supported their engineering identity development in some way. However, neither Victoria nor Addison developed an engineering possible self. When asked how she would feel if she found out that she had become an engineer, Victoria said, "I'd be shocked" and attributed this to her dislike of math. Similarly, Addison said that she would be disappointed if she became an engineer as she does not think the work an engineer does is interesting. It should be noted that Addison did not appear to develop a more accurate view of engineering after the Programming Robots badge (Girl Scouts of the USA, 2018b) unlike the other members of her troop, which may have contributed to the lack of identity growth.

Within the hybrid troop, Ella, Mia, and Ava indicated that they may be interested in engineering in the future. However, Mia's and Ava's conceptions of engineering, which are discussed in detail in the following section, lend doubt to that assertion. During their interviews, Mia described engineering as interior design, and Ava associated engineering with baking. As these are not typically considered to be part of the engineering field, it is difficult to say that they are truly interested in engineering. However, Ella maintained her engineering possible self related to creating and inventing. She said, "It would be really cool. I would probably invent something. I always liked creating things. I would like to be an engineer, so it would be pretty fun."

The remainder of the hybrid troop did not develop engineering possible selves. Elizabeth, Grace, Harper, and Avery all attributed this to a dislike of math or poor math skills. For Elizabeth, this is consistent with her pre-interview. Grace, Harper, and Avery had not previously connected engineering and math as related subjects though they had previously indicated a dislike for math. In the post-interview, when asked what skills she would need to be an engineer, Harper said, "You would need to be good at math, science. I'm not too sure what else." She later said, "I'm not very good at math and I don't enjoy it." While other members of the hybrid troop did not develop engineering possible selves, other reasons were given. Evelyn, along with Elizabeth, described engineering as *"boring"* and thus they were not interested in pursuing it.

Table 3 summarizes how participants' possible selves evolved across the two interviews. Each of the categories shown in Table 3 indicates an engineering possible self category which the participant fell into. In the pre-interview, participants were initially sorted into "no possible self" and "engineering possible self" based on their interview responses. Those who did not indicate an engineering possible self were further sorted into categories, as shown in Table 3, based on their interview responses. The interviews were similarly categorized in the post-interview; however, the interviews were not further sorted beyond their initial categorization as participants' reasons for not envisioning an engineering possible self had generally remained the same.

Understanding of Engineering

Following the experience with the Programming Robots badge, participants showed a slightly improved understanding of engineers and engineering using the NGSS conceptualization of engineering described earlier. An accurate understanding of engineering is essential for developing a possible self identity related to engineering. If a student's perception of engineers and engineering is incongruent with who they view themselves to be and who they are becoming, then a student may never entertain engineering as a possibility for themself.

Pre-Interviews

Initially, nearly all the participants held stereotypical views of engineers and engineering, which is evident in the DAET images. Of the 15 participants, 12 drew stereotypical images of engineering as defined by previous research using the DAET (e.g., Carr et al., 2012; Fralick et al., 2009). These views primarily included that of an engineer as a mechanic or as a construction worker. Three participants drew images that would be generally considered a more accurate representation of engineering as they showed elements of design and other components of engineering that appear in the NGSS (2013) conceptualization of engineering.

Table 3
Possible selves across interviews.

		Pre-interview				Post-interview		
		No possible self						
Pseudonym	Troop	No skills/math ability	No interest	Interest in engineering	Engineering possible self	No possible self	Possible interest in career	Engineering possible self
Addison	Online		X			X		
Aubrey	Online		X					X
Ava	Hybrid	X					X	
Avery	Hybrid			X		X		
Chloe	Hybrid	X				X		
Elizabeth	Hybrid	X				X		
Ella	Hybrid				X			X
Evelyn	Hybrid		X			X		
Grace	Hybrid		X			X		
Hannah	Online				X			X
Harper	Hybrid		X			X		
Mia	Hybrid			X			X	
Lily	Online		X					X
Victoria	Online	X				X		
Zoey	Online				X			X

Six participants (Avery, Addison, Aubrey, Mia, Evelyn, and Zoey) drew and described engineers who were performing maintenance on vehicles. For example, Avery described her drawing, shown in Figure 2, as "I thought of an engineer fixing a car, I don't know…Well, I thought he would be on the skateboard trying to fix the underneath of the car."

Avery described an engineer as "they should be good at fixing things and knowing how to do what they're doing" and that engineers need "math and science…maybe math to help get this stuff in the right place, and science because I don't know, it's just a guess." Avery's grandmother told her that she had drawn a mechanic rather than an engineer, but when asked what she would draw now to represent an engineer, Avery said "I don't know, a person" indicating that even though she now knew that engineers are not mechanics, she did not have a strong understanding of engineering.

Three participants (Hannah, Victoria, and Ella) drew less stereotypical representations of engineers at work. Hannah described her drawing, shown in Figure 3, as "She's making blueprints because she's going to make a robot…A nurse robot."

Here, Hannah showed an understanding that design, not just maintenance and assembly, is part of engineering and so shows a slightly better understanding of engineering than other participants. Similarly, Victoria described engineering as someone who uses data to make decisions about what they are designing and building based on that data, and Ella describes engineering as planning and building new things, using the example of a rover.

Eight of the 15 participants (Lily, Zoey, Elizabeth, Ella, Evelyn, Grace, Harper, and Mia) indicated that they had participated in some kind of engineering experience prior to the Programming Robots badge. These ranged from recent bridge and tower building science class projects to more distant experiences, such as a weekend program run by the local science museum with Girl Scouts, and experiences at home with toys like LEGO®. However, many participants struggled to identify why the experience they described was engineering. In some instances, they had been told that it was engineering.

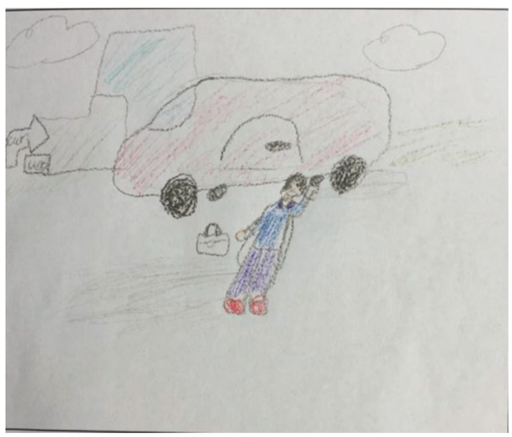

Figure 2. Avery's pre-interview DAET.

Figure 3. Hannah's pre-interview DAET.

http://dx.doi.org/10.7771/2157-9288.1346

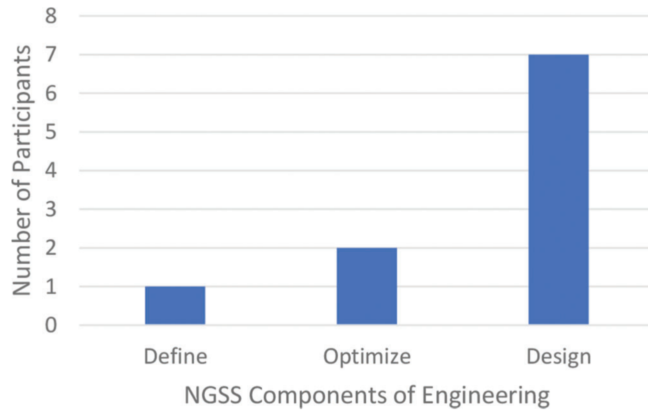

Figure 4. Identified NGSS components of engineering.

However, when asked to draw and describe engineers at work, the participants described mechanics and construction workers as part of their description indicating that these experiences may not have provided long-lasting information regarding the critical components of engineering.

Analysis of the interviews for the NGSS components of engineering design (NGSS, 2013) shows similar results. Figure 4 shows how many participants described in their interview and in their DAET each component of engineering as defined by NGSS (2013).

As seen in Figure 4, design was the most frequently exhibited component, as seven participants' interviews (Ella, Avery, Grace, Elizabeth, Hannah, Victoria, and Chloe) showed indications of design. This most frequently occurred when participants discussed sketching ideas or making blueprints. Five participants (Ella, Avery, Grace, Elizabeth, and Hannah) exhibited only design in their interview and did not include any evidence of define or optimize. Optimize occurred next most frequently, with two participants (Chloe and Victoria) discussing optimization in their interviews. Both Chloe and Victoria showed optimization by discussing testing as part of engineering with Chloe saying about her engineer, "She likes to test things out." Victoria alone exhibited defining as part of her description of what the engineering in her DAET was doing. She said:

> [They're] getting the information that they need for their project…Making sure they have measurements for length and width so it can fit in the direct spot it needs to be, and then how big the battery needs to be charged and how much time they have on it.

However, eight participants showed no signs of any of the components of engineering during their interviews.

Post-Interviews

Across both troops, participants generally showed an improved understanding of engineering following their experience with the Programming Robots badge. This can be seen in both the DAET results and when looking for evidence of the NGSS components of engineering (NGSS, 2013). The DAET drawings and descriptions from the post-interviews can be sorted into three categories: descriptions related to the engineering badge activities; descriptions related to engineering, though not related to the badge work; and a few participants who maintained stereotypical views of engineering.

Six participants (Aubrey, Elizabeth, Lily, Hannah, Ella, and Evelyn) described engineering related to the badge activities, and these are split into two categories: those who described engineering as computer programming and those who described engineering in relation to robots. Hannah, Ella, and Evelyn described engineering related to building and designing robots. For Hannah, her second drawing, shown in Figure 5, is very similar to her first drawing, and she describes the drawing as, "She's making blueprints to make a robot."

Similarly, Ella described engineering as, "Creating things. The creation of new things. It can often include robotics, but it actually doesn't have to be always. Engineering isn't just all robots." Considering that Ella's and Hannah's conceptions of engineering appear to have remained relatively unchanged between the two interviews, the badge activities may have served to reinforce their understanding of engineering. By contrast, Evelyn had initially described engineering as someone who worked on planes but in her post-interview described engineering as, "I would probably be building something like a robot…you would have to program it to move and stuff and you would have to make sure all the things are working right." Indicating that she has changed her understanding of engineering following the experience with the engineering badge.

Figure 5. Hannah's post-interview DAET.

Figure 6. Harper's post-interview DAET.

Three participants (Harper, Victoria, and Zoey) described engineering in ways that are unrelated to the badge activities but show indications of a developing understanding of engineering. For example, Harper describes her drawing, shown in Figure 6, as "I am designing a tower."

Harper discussed what she would need to know to design the tower saying, "Science because gravity and proportions and stuff. And then math because you need to know how big it needs to be and how much space it's going to take up." Design was a focus of several activities in the engineering badge, but these participants applied it to contexts other than those of the activities in the badge.

There were five participants (Addison, Mia, Grace, Ava, and Avery) who again drew stereotypical or other inaccurate images of engineering. These included a technician assembling LED strips (Addison), a designer (Mia), a construction worker (Grace), a baker (Ava), and someone fixing a plane (Avery). As previously discussed, conceptions of engineering as a technician, construction worker, or mechanic are very common (Fralick et al., 2009). Ava's drawing of a baker is somewhat puzzling, and she never clearly connects baking and engineering saying "Well, I just thought about baking because I've had a lot of birthdays recently and it just makes me think of cakes and cookies and all kinds of stuff." However, Ava defined engineering later in her interview as, "Kind of think of building things and making things…If you were talking about building a house maybe, I would say that's something you could do." Regardless of which of Ava's descriptions is chosen, Ava either continued to hold a stereotypical or inaccurate understanding of engineering. Of these five

Table 4
NGSS engineering design components.

Participant	Pre-interview	Post-interview
Addison	None	None
Aubrey	None	None
Ava	None	None
Avery	Design	Design
Chloe	Optimize, design	None
Elizabeth	Design	Optimize
Ella	Design	Design
Evelyn	None	Optimize, design
Grace	Design	Design
Hannah	Design	Optimize, design
Harper	None	Define, design
Mia	None	Design
Lily	None	Optimize
Victoria	Define, optimize, design	Define
Zoey	None	Define, design

participants, four appear to have developed very little in their understanding of engineering. It should be noted that these four participants (Addison, Grace, Mia, and Avery) each only attended one of two meetings.

Comparing participants' interviews to the NGSS engineering design component (NGSS, 2013), many participants showed evidence of more components of engineering than they did in their initial interview. As seen in Table 4, five of the eight participants who initially showed none of the components of engineering design in their pre-interview showed at least one in their post-interview. Additionally, Hannah and Elizabeth both showed evidence of different engineering design components in their post-interview than they did in their pre-interview. These additional elements of engineering that emerge in the post-interviews provided further evidence that the participants' understanding of engineering grew following the badge work.

Examining Table 4 indicates that several participants (Addison, Aubrey, and Ava), appeared to not have grown in their understanding of engineering and that Chloe and Victoria understood engineering less well as they exhibited fewer components of engineering in their post-interview than they did in their pre-interview. However, it should be noted that since the interview protocol did not specifically seek to understand participants' understanding of engineering through this framework, the absence of a component does not necessarily indicate that the participant did not see it as part of engineering, simply that it did not come up in our conversation.

Discussion

We sought to provide insight into how a Girl Scout engineering badge might impact engineering identity through the lens of PST, as well as girls' understanding of engineering work. Though each participant had a unique experience related to their understanding of engineering, themselves as engineers, and the Programming Robots badge, two main patterns emerged from the data. First, across both troops, participants displayed an increased understanding of engineering following the badge workshops. Second, there was a limited impact on participants' imagined possible selves as an engineer evident in the interviews, although the participants in the online troop were more likely to indicate an engineering possible self than the participants in the hybrid troop. Below, we expand on the impact of the Programming Robots badge on these two patterns.

Pattern 1: Limited Impacts on Engineering as a Possible Self

Overall, limited impacts were observed on participants' development of engineering possible selves. Three participants (Hannah, Ella, and Zoey) maintained the engineering possible selves that they began the study with. Two participants (Aubrey and Lily) showed signs of developing engineering possible selves. However, the remaining 10 participants showed no signs of developing engineering possible selves.

Many participants started the study with and maintained possible selves related to their current interests. Markus and Nurius (1986) said, "The pool of possible selves derives from the categories made salient by the individual's particular sociocultural and historical context and from the models, images, and symbols provided by the media and by the individual's immediate social experiences" (p. 954). Thus, it is to be expected that the participants' current experiences are driving their views of themselves in the future. For the participants who showed no growth in engineering identity, based on the interview data, we attributed this to three factors: beliefs about math ability, outside influences, and badge environment.

First, many participants indicated both in the pre- and post-interviews that they did not like or were not good at math and therefore were not interested in becoming engineers. Previous research suggests that these views of math and engineering are not uncommon and likely several factors contribute. First, a drop in interest and perceived ability in math around middle school is well documented, especially in middle school girls (e.g., Muzzatti & Agnoli, 2007; Steffens et al., 2010). Since engineering is often perceived as for people who are good at math and science (Burtner, 2005), it is unsurprising that participants who view themselves as bad at math would not have developed future selves related to engineering. Since it is outside the scope of this study, we did not probe into what "bad at math" meant for these participants or ask for evidence of poor performance. While there has been a historical perception that girls fall behind boys in math (e.g., Isaacs, 2001), more recent data indicate that this is not the case, and girls typically perform on a par with or better than boys (e.g., Gilley & Begolly, 2005; Hill et al., 2010; Schreuders et al., 2009). However, previous research has indicated that middle school girls have lower self-efficacy in math than boys do (e.g., Louis & Mistele, 2012), which may contribute to the perception that they are "bad at math." Nonetheless, whether they are actually "bad at math" or simply perceive themselves to be, this group of participants had not considered engineering as a possible self because of their perception of their math ability or their math interest. Additionally, the Programming Robots badge curriculum does not include any math content, so unsurprisingly, beliefs regarding math and math ability remained unchanged.

Second, even in this relatively short period, we saw evidence of outside influences on what participants believe about engineering. This is most evident in the connection between math and engineering. While Grace, Harper, and Avery had expressed a dislike of math, none of them had linked math to engineering in the pre-interview. However, by the time the post-interview occurred all three of them had drawn a connection between engineering and math that did not previously seem to exist. The Programming Robots badge does not include any discussion of math, and none of the research team members could recall any discussions or questions regarding math. While we cannot discount the possibility that these conversations took place between troop members, we do not have any evidence of how Grace, Harper, and Avery developed the connection between math and engineering. However, these connections could have been drawn through conversations with peers. For example, other troop members who had already made a connection between math and engineering, such as Elizabeth, may have shared this connection with them. Additionally, this connection may have occurred through conversations with trusted adults, such as parents, guardians, troop leaders, or teachers. While we did not see evidence of the discussion of the connection between math and engineering with parents or guardians, conversations regarding engineering did occur for other elements of the study, as described relating to Avery's DAET drawing. While this conversation did not involve math and engineering, the occurrence of an influential conversation is indicative that participants were discussing the badge activities with their parents and guardians, so conversations regarding math and engineering may have also occurred. Previous research has indicated that family interactions can be an important influence on career development and goal setting (e.g., Hargrove et al., 2002; Kramer et al., 2019), so this outside influence is not surprising, though must be understood and accounted for.

Third, the environments in which the two troops completed the Programming Robots badge were very different. For example, the hybrid troop met together in person and the research team joined via Zoom. For the first meeting, we had a single vantage point of a long picnic table with all the troop members seated at it, and for the second meeting, the girls were split into two groups of approximately eight girls in each group where each gathered around a table and laptop. This limited vantage point made the facilitation of the activities incredibly difficult, and this was reflected in the engagement of the participants. In the online troop, we observed relatively high and consistent engagement and participation of most of the troop members. With the hybrid troop, we observed many instances of disengagement and lack of participation. These manifested through unrelated conversation, lack of focus, and participants running around the meeting space. These differences in engagement may have been related to the perceived accessibility of the facilitators. With the online troop, we were all on the same platform and no participant was closer to the facilitator than the others. In contrast, especially at the hybrid first meeting, there were certainly participants who were significantly farther from the facilitators than others. Thus, the facilitators may have seemed to be less accessible. We believe that this could be best explained by the theory of situated learning (Lave & Wenger, 1991) where the context in which the learning is occurring impacts the outcomes, which is consistent with literature from formal pre-college engineering education research (e.g., Mena et al., 2009). Due to the different levels of engagement observed, it is difficult to directly compare the impacts on engineering identity among the participants between the two groups, though future work may shed light on these differences.

Overall, there seemed to be very limited impact on the participants' engineering possible selves development, though some evidence was seen in participants in the online troop. However, it should be noted that identity development, especially in adolescence, is an ongoing process (Erikson, 1968), and while this experience did not result in an immediate impact for many participants, its longer-term impact is unknown. As the NRC (2015) notes, "A single experience may not have an immediate recognizable or detectable effect on knowledge or interest but may have a relatively profound effect if it serves to orient, inspire, or motivate a young person to be open to new STEM learning opportunities" (p. 33). It is therefore important to investigate how experiences accumulate and how cumulative impact affects pre-college students.

Pattern 2: Improved Understanding of Engineering

Overall, most participants exhibited an improved understanding of engineering following the badge activities. However, four participants maintained stereotypical or inaccurate views of engineering. We believe that this was related to a lack of engagement with the material, as these participants all only attended one of two meetings.

Initially, with only a few exceptions, most participants had a very limited understanding of what engineers do and the kinds of problems that engineers solve. However, holding views of engineers as mechanics, technicians, or even train drivers is relatively common among pre-college students. In a study by Fralick et al. (2009), it was found that nearly 20% of DAET drawings done by middle schoolers contained passenger vehicles and 13% contained trains or train tracks. Similarly, Carr et al. (2012 found in their analysis images of engineers as construction workers to be one of the most common conceptions among their participants. Additionally, Fralick et al. (2009) found that the most common action attributed to an engineer in the drawing set was "making/fixing/working with hands" with 31% of the drawings appearing to contain this action, which is also consistent with the set of drawings produced by this study's participants. By comparing this group of participants to the larger body of literature in pre-college engineering, we can see that they were not abnormal in their perception of engineering and engineers. This also indicates that there is little to no biases or knowledge related to higher-than-average or lower-than-average exposure before the Programming Robots badge among most of these participants.

However, the participants' general lack of understanding regarding engineering was somewhat surprising given that eight of them described some form of previous engineering experience. Given opportunities to engage in engineering, we would expect participants to exhibit a better understanding of engineering as other research has indicated (e.g., Bystydzienski et al., 2015; Wei & Hill, 2018), yet of the participants with previous engineering experience, only Ella described engineering in a non-stereotypical manner, as in her pre-interview she described engineering related to designing and building a rover. The remainder of the participants with previous engineering experience described engineers and their roles related to jobs like construction workers or mechanics. It is not clear why some participants continued to perceive engineering as construction workers and mechanics following previous engineering exposure. Many factors could be at play ranging from factors involving the experiences themselves to the level at which the participants engaged in these activities. The apparent lack of retention from previous engineering experiences raises the question of the long-term impacts of this experience as well. There has been very little research on the long-term retention and impact of informal engineering programs, so it is difficult to speculate the reasoning.

Following the Programming Robots badge, participants, in general, showed a better understanding of engineering than they did initially. An increased understanding of engineering is common following exposure to engineering content in both formal (e.g., Capobianco et al., 2015; Carr et al., 2012; Mena et al., 2009) and informal (e.g., Bystydzienski et al., 2015; Wei & Hill, 2018) settings. The activities within the engineering badge may have allowed participants to engage in authentic engineering activities, such as designing and troubleshooting an algorithm, and allowed participants to better understand engineers and engineering work. However, as is noted above, some participants seemed to have maintained a stereotypical or limited view of engineering and continued to primarily describe engineering as mechanics and technicians. As all four of these participants attended only one of two sessions, we posit that this limited engagement with the material impacted their understanding of engineering. Additional factors could also be at work. For example, did they engage meaningfully with the material? Because of the virtual environment, it was difficult to observe individual participants, so we cannot comment on these participants' individual levels of engagement. Just being in the room for the badge workshop may not be sufficient to develop an understanding of engineering. While most participants showed some development in their view of engineering, one participant, Mia, moved from one inaccurate understanding of engineering to another inaccurate understanding of engineering. This resulted from a misunderstanding of the word "design" and its multiple definitions. While this appears to be an isolated incident in this population, this confusion is important to note as being clear with what "design" means in an engineering context may be critical so that participants develop an accurate understanding of engineering and engineering design.

Additionally, due to the timing of the research, the results of this study cannot be compared to the impacts of this informal engineering experience before the COVID-19 pandemic. However, these results do indicate that virtual environments may be an effective way to engage pre-college students with engineering content. These virtual experiences may further broaden participation by allowing pre-college students who would not typically have access to engineering in their schools or communities the means to engage with engineering content in a meaningful way. The engineering education research community must continue to study these settings and how they can be most impactful for a variety of participants.

Conclusion and Future Work

Through this research, we examined how an informal engineering experience could impact engineering identity conceptualized through PST. These findings revealed that there were slight impacts on engineering identity among some participants. For many participants, there was limited impact on how they viewed themselves as future engineers. This was specifically true for participants who considered themselves "bad at math." Engineering and math may be so tightly entwined that it would be difficult to persuade a person who perceives themselves to be bad at math that engineering is even a possibility for them. However, despite limited identity impacts, there is evidence for growth in understanding of engineering across most participants. Participants began the study by describing engineering stereotypically, mostly as mechanics and construction workers, and many showed no signs of the NGSS components of engineering design (NGSS, 2013). However, following the engineering badge, fewer participants described engineering stereotypically and many participants' descriptions of engineering included more components of engineering design than they had previously. Together these findings show that this informal engineering experience has the potential to impact both engineering identity development and knowledge of engineering. While the scope of this study is small, it serves as an initial investigation of the under-researched informal engineering education space and provides initial indications that these experiences may provide an impactful way to reach pre-college students who may not be otherwise exposed to engineering.

Future Work

These findings are encouraging, but there is a significant need for more research. For example, while this and other studies on informal engineering experiences (e.g., Hughes et al., 2013; Wei & Hill, 2018) focus on one experience, little is known about how the elements of the "STEM learning ecosystem" (NRC, 2015) work together. This is important to understand as there was evidence of outside influence on how participants perceived engineering. To better understand how the many experiences that pre-college students have within the STEM learning ecosystem coalesce and impact engineering identity development, it may be more effective to focus on the range of experiences that a person has rather than individual experiences.

Secondly, this work occurred in the context of an unprecedented global health crisis: the COVID-19 pandemic. Generally, prior to the pandemic, these types of experiences were limited to in-person experiences. This work shows that with some adaptation online or hybrid deliveries of informal experiences can be implemented. Implementing these types of activities in an online or hybrid environment has the potential to increase access to engineering, as it may allow for a group of students to virtually engage with an expert or facility outside of their local community. However, more work is needed to understand the difference between the impacts of informal experiences in a range of modalities. Similarly, additional work is needed to develop sets of evidence-based recommendations for successfully implementing informal engineering experiences across these modalities.

Moreover, the Girl Scouts and other organizations which offer similar programming should consider adjusting offerings based on research results. For example, in this study, many participants cited their math ability as a reason that they could not see an engineering possible self. Findings such as these might serve as the inspiration for offerings such as experiences that highlight the utility of math. Additional studies would be needed to better inform these programming decisions to support engineering identity.

Finally, the long-term impact of these experiences remains unknown. While there is some evidence of impact both in terms of identity development and engineering knowledge, more work is needed to understand if or how these impacts remain in the future. Understanding how all the parts of pre-college engineering education, both formal and informal, work together and across time would allow engineering educators to leverage the best of both worlds. Understanding how identity develops in pre-college students is essential for the field as we continue to seek to close the persistent gender gap in the engineering field. Further research is needed to understand how these virtual experiences vary from their in-person counterparts. Understanding these variations and how virtual experiences may be leveraged is important to broadening participation in engineering.

Acknowledgments

This study was supported by the Battelle Engineering, Technology and Human Affairs (BETHA) endowment. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the BETHA endowment. Many thanks to the Girl Scout staff members, volunteers, troop leaders, parents, and girls who made this research possible. We would also like to thank Dr. Lindsay Burns, Dr. Renee Desing, Ms. Renee Pelan, Dr. Cassie Wallwey, and Ms. Meg West for assisting in data collection. Additional thanks to Dr. Desing and Dr. Wallwey for providing critical feedback on early drafts of this manuscript, as well as Ms. West for data quality reviews. Finally, thank you to Ms. Emma Krabbe and Mr. Gregory Mogren for their assistance in finalizing this paper.

Author Bios

Dr. Abigail M. Clark (a-clark.5@onu.edu) is an Assistant Professor in the Department of Mechanical Engineering at Ohio Northern University. She earned her Ph.D. in engineering education from The Ohio State University. Her research interests include identity development in informal pre-college engineering and women's experiences in the engineering field.

Dr. Rachel Louis Kajfez (Kajfez.2@osu.edu) is an Associate Professor in the Department of Engineering Education at The Ohio State University. She earned her Ph.D. in engineering education from Virginia Tech. Her research interests focus on motivation, identity, first-year engineering programs, mixed-methods research, and innovative approaches to teaching.

Reference

Advancing Informal STEM Learning (AISL). (n.d.). Retrieved March 7, 2022, from https://beta.nsf.gov/funding/opportunities/advancing-informal-stem-learning-aisl

Ashforth, E., & Mael, F. (1989). Social identity theory and the organization. *Academy of Management Review*, *14*(1), 20–39. https://doi.org/10.5465/AMR.1989.4278999

Auger, R. W., Blackhurst, A. E., & Wahl, K. H. (2005). The development of elementary-aged children's career aspirations and expectations. *Professional School Counseling*, *8*(4), 322–329. https://www.jstor.org/stable/42732626

Award and badge explorer. (n.d.). Retrieved May 17, 2019, from https://www.girlscouts.org/en/our-program/badges/badge_explorer.html

Beam, T., Pierrakos, O., Constantz, J., Johri, A., & Anderson, R. (2009). Preliminary findings on freshmen engineering students' professional identity: Implications for recruitment and retention. *American Society for Engineering Education Annual Conference & Exposition*, 14.968.1–14.968.12.

Buontempo, J., Riegle-Crumb, C., & Patrick, A. (2017). Examining gender differences in engineering identity among high school engineering students. *Journal of Women and Minorities in Science and Engineering*, *23*(3), 271–287. https://doi.org/10.1615/JWomenMinorScienEng.2017018579

Burtner, J. (2005). The use of discriminant analysis to investigate the influence of non-cognitive factors on engineering school persistence. *Journal of Engineering Education*, *94*(3), 335–338. https://doi.org/10.1002/j.2168-9830.2005.tb00858.x

Bystydzienski, J. M., Eisenhart, M., & Bruning, M. (2015). High school is not too late: Developing girls' interest and engagement in engineering careers. *Career Development Quarterly*, *63*(1), 88–95. https://doi.org/10.1002/j.2161-0045.2015.00097.x

Cantrell, P., & Ewing-Taylor, J. (2009). Exploring STEM career options through collaborative high school seminars. *Journal of Engineering Education*, *98*(3), 295–303. https://doi.org/10.1002/j.2168-9830.2009.tb01026.x

Capobianco, B. M., French, B. F., & Diefes-Dux, H. A. (2012). Engineering identity development among pre-adolescent learners. *Journal of Engineering Education*, *101*(4), 698–716. https://doi.org/10.1002/j.2168-9830.2012.tb01125.x

Capobianco, B. M., Yu, J. H., & French, B. F. (2015). Effects of engineering design-based science on elementary school science students' engineering identity development across gender and grade. *Research in Science Education*, *45*(2), 275–292. https://doi.org/10.1007/s11165-014-9422-1

Carlone, H. B., Scott, C. M., & Lowder, C. (2014). Becoming (less) scientific: A longitudinal study of students' identity work from elementary to middle school science. *Journal of Research in Science Teaching*, *51*(7), 836–869. https://doi.org/10.1002/tea.21150

Carr, R. L., Diefes-Dux, H. A., & Horstman, B. J. (2012). Change in elementary student conceptions of engineering following an intervention as seen from the draw-an-engineer test. *American Society for Engineering Education Annual Conference & Exposition*, 25.299.1–25.299.12. https://doi.org/10.18260/1-2--21057

Cech, E., Rubineau, B., Silbey, S., & Seron, C. (2011). Professional role confidence and gendered persistence in engineering. *American Sociological Review*, *76*(5), 641–666. https://doi.org/10.1177/0003122411420815

Chapman, A., Rodriguez, F. D., Pena, C., Hinojosa, E., Morales, L., Del Bosque, V., Tijerina, Y., & Tarawneh, C. (2020). "Nothing is impossible": Characteristics of Hispanic females participating in an informal STEM setting. *Cultural Studies of Science Education*, *15*(3), 723–737. https://doi.org/10.1007/s11422-019-09947-6

Chubin, D. E., May, G. S., & Babco, E. L. (2005). Diversifying the engineering workforce. *Journal of Engineering Education*, *94*(1), 73–86. https://doi.org/10.1002/j.2168-9830.2005.tb00830.x

Clark, A. M., & Kajfez, R. L. (2019). Engineering identity in pre-college students: A literature review. *American Society for Engineering Education Annual Conference & Exposition*. https://doi.org/10.18260/1-2--32727

Congressional Commission on the Advancement of Women and Minorities in Science Engineering and Technology Development. (2000). *Land of plenty: Diversity as America's competitive edge in science, engineering, and technology*. https://doi.org/10.1061/(ASCE)1532-6748(2001)1:4(27)

Corbett, C., & Hill, C. (2015). *Solving the equation: The variables for women's success in engineering and computing*. American Association of University Women. https://www.aauw.org/app/uploads/2020/03/Solving-the-Equation-report-nsa.pdf

Douglas, K. A., Mihalec-Adkins, B. P., & Diefes-Dux, H. A. (2014). Boys and girls engineering identity development in early elementary. *American Society for Engineering Education Annual Conference & Exposition*, 24.235.1–24.235.8. https://doi.org/10.18260/1-2--20126

Erikson, E. H. (1968). *Identity: Youth and crisis* (1st ed.). W. W. Norton Company.

Felix, M. S. (2018). My family, my self: Reflections on family interactions of Malaysian gay men within the Asian cultural context. *Asia-Pacific Social Science Review*, *17*(3), 98–108.

Fralick, B., Kearn, J., Thompson, S., & Lyons, J. (2009). How middle schoolers draw engineers and scientists. *Journal of Science Education and Technology*, *18*(1), 60–73. https://doi.org/10.1007/s10956-008-9133-3

Gee, J. P. (2000). Chapter 3: Identity as an analytic lens for research in education. *Review of Research in Education*, *25*(1), 99–125. https://doi.org/10.3102/0091732X025001099

Gilley, J., & Begolly, J. (2005). Great progress, great divide: The need for evolution of the recruitment model for women in engineering. *American Society for Engineering Education Annual Conference & Exposition*, 7003–7013. https://doi.org/10.18260/1-2--15484

Girl Scouts of the USA. (n.d.). *Girl Scout STEM pledge*. https://www.girlscouts.org/en/adults/donate/STEM-pledge/STEMpledge.html

Girl Scouts of the USA. (2018a). *Cadette think like an engineer journey guide*.

Girl Scouts of the USA. (2018b). *Programming Robots*.

Godwin, A., Sonnert, G., & Sadler, P. M. (2015). The Influence of out-of-school high school experiences on engineering identities and career choice. *American Society of Engineering Education Annual Conference & Exposition*, 26.1552.1–26.1552.14. https://doi.org/10.18260/p.24889

Gonsalves, A., Rahm, J., & Carvalho, A. (2013). "We could think of things that could be science": Girls' re-figuring of science in an out-of-school-time club. *Journal of Research in Science Teaching*, *50*(9), 1068–1097. https://doi.org/10.1002/tea.21105

Hargrove, B. K., Creagh, M. G., & Burgess, B. L. (2002). Family interaction patterns as predictors of vocational identity and career decision-making self-efficacy. *Journal of Vocational Behavior*, *61*(2), 185–201. https://doi.org/http://dx.doi.org/10.1006/jvbe.2001.1848

Hatmaker, D. M. (2013). Engineering identity: Gender and professional identity negotiation among women engineers. *Gender, Work and Organization*, *20*(4), 382–396. https://doi.org/10.1111/j.1468-0432.2012.00589.x

Heiser, S. (2017). *More women than men enrolled in U.S. medical schools in 2017*. Association of American Medical Colleges. https://news.aamc.org/press-releases/article/applicant-enrollment-2017/

Hill, C., Corbett, C., & St Rose, A. (2010). *Why so few?* (1st ed.). American Association of University Women. https://ww3.aauw.org/research/why-so-few/

Holmes, S., Redmond, A., Thomas, J., & High, K. (2012). Girls helping girls: Assessing the influence of college student mentors in an afterschool engineering program. *Mentoring and Tutoring: Partnership in Learning*, *20*(1), 137–150. https://doi.org/10.1080/13611267.2012.645604

Hug, S., & Eyerman, S. (2021). "I like that girl power": Informal/formal learning ecosystems that support young women's engagement in STEM. *International Journal of Gender, Science and Technology*, *13*(2), 110–133. https://genderandset.open.ac.uk/index.php/genderandset/article/view/709

Hughes, R. M., Nzekwe, B., & Molyneaux, K. J. (2013). The single sex debate for girls in science: A comparison between two Informal science programs on middle school students' STEM identity formation. *Research in Science Education*, *43*(5), 1979–2007. https://doi.org/10.1007/s11165-012-9345-7

Hynes, M. M., Mathis, C., Purzer, S., & Rynearson, A. (2017). Systematic review of research in P-12 engineering education from 2000–2015. *International Journal of Engineering Education*, *33*(1), 453–462.

Isaacs, B. (2001). Mystery of the missing women engineers: A solution. *Journal of Professional Issues in Engineering Education & Practice*, *127*(2), 85–91. https://doi.org/10.1061/(ASCE)1052-3928(2001)127:2(85)

Jue, J., & Ha, J. H. (2018). The professional identity, career commitment and subjective well-being of art therapy students. *Arts in Psychotherapy*, *57*, 27–33. https://doi.org/10.1016/j.aip.2017.10.007

Kekelis, L. S. (2017). Techbridge girls: Inspiring a girl to change the world through STEM. In L. R. Wiest, J. E. Sanchez, & H. G. Crawford-Ferre (Eds.), *Out-of-school-time STEM programs for females* (1st ed., pp. 55–79). Information Age Publishing, Inc.

Kettler, N., Frenzel Baudisch, N., Micheelis, W., Klingenberger, D., & Jordan, A. R. (2017). Professional identity, career choices, and working conditions of future and young dentists in Germany: Study design and methods of a nationwide comprehensive survey. *BMC Oral Health*, *17*(1), 1–12. https://doi.org/10.1186/s12903-017-0417-y

Kleinfeld, J., & Shinkwin, A. (1983). Lessons out-of school: Boy Scouts, Girl Scouts and 4-H Clubs as educational environments. *American Educational Research Association*.

Knight, M., & Cunningham, C. (2004). Draw an engineer test (DAET): Development of a tool to investigate students' ideas about engineers and engineering. *American Society for Engineering Education Annual Conference & Exposition*, 9.482.1–9.482.11. https://doi.org/10.18260/1-2--12831

Kramer, A., Wallwey, C., Thanh, G., Dringenberg, E., & Kajfez, R. (2019). A narrative-style exploration of undergraduate engineering students' beliefs about smartness and identity. *Proceedings: Frontiers in Education Conference*. https://doi.org/10.1109/FIE43999.2019.9028388

Laursen, S. L., Thiry, H., Archie, T., & Crane, R. (2013). Variations on a theme: Characteristics of out-of-school time science programs offered by distinct organization types. *Afterschool Matters*, *17*, 36–49. https://www.niost.org/2013-Spring/variations-on-a-theme-characteristics-of-out-of-school-time-science-programs-offered-by-distinct-organization-types

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lee, D., McAlister, A., Ehlert, K., Faber, C., Kajfez, R., Creamer, E., & Kennedy, M. (2019). Enhancing research quality through analytical memo writing in a mixed methods grounded theory study implemented by a multi-institution research team. *2019 IEEE Frontiers in Education Conference*. https://doi.org/10.1109/FIE43999.2019.9028469

Lichtman, M. (2013). *Qualitative research in education: A user's guide* (3rd ed.). Sage Publications.

Lips, H. M. (2004). The gender gap in possible selves: Divergence of academic self-views among high school and university students. *Sex Roles*, *50*(5–6), 357–371. https://doi.org/10.1023/B:SERS.0000018891.88889.c9

Louis, R. A., & Mistele, J. M. (2012). The differences in scores and self-efficacy by student gender in mathematics and science. *International Journal of Science and Mathematics Education*, *10*(5), 1163–1190. https://doi.org/10.1007/s10763-011-9325-9

Markus, H. R., & Nurius, P. (1986). Possible selves. *American Psychologist*, *41*(9), 954–969. https://doi.org/10.1037/0003-066X.41.9.954

Matusovich, H., Streveler, R., & Miller, R. (2010). Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values. *Journal of Engineering Education*, *99*(4), 289–303. https://doi.org/10.1002/j.2168-9830.2010.tb01064.x

Mena, I., Capobianco, B., & Diefes-dux, H. (2009). Significant cases of elementary student development of engineering perceptions. *American Society for Engineering Education Annual Conference & Exposition*, 14.1057.1–14.1057.16. https://doi.org/10.18260/1-2--4559

Monaco, P. A., Cloutier, A., Yew, G. Z., Brundrett, M. M., Christenson, D., & Morse, A. N. (2016). Design of an interactive multidisciplinary residential summer program for recruitment of high school females to engineering. *American Society for Engineering Education Annual Conference*. https://doi.org/10.18260/p.26684

Morelock, J. R. (2017). A systematic literature review of engineering identity: Definitions, factors, and interventions affecting development, and means of measurement. *European Journal of Engineering Education*, *42*(6), 1240–1282. https://doi.org/10.1080/03043797.2017.1287664

Muzzatti, B., & Agnoli, F. (2007). Gender and mathematics: Attitudes and stereotype threat susceptibility in Italian children. *Developmental Psychology*, *43*(3), 747–759. https://doi.org/10.1037/0012-1649.43.3.747

National Research Council. (2015). *Identifying and supporting productive STEM programs in out-of-school settings*. National Academies Press. https://doi.org/10.17226/21740

National Science Board. (2020). *Science & engineering indicators*. https://doi.org/10.1097/00001888-199005000-00011

Next Generation Science Standards. (2013). *Appendix I: engineering design in the NGSS*. Next Generation Science Standards. https://www.nextgenscience.org/sites/default/files/resource/files/Appendix I - Engineering Design in NGSS - FINAL_V2.pdf

Nuttin, J. R. (1964). The future time perspective in human motivation and learning. *Acta Psychologica*, *23*(C), 60–82. https://doi.org/10.1016/0001-6918(64)90075-7

Oyserman, D., Bybee, D., & Terry, K. (2006). Possible selves and academic outcomes: How and when possible selves impel action. *Journal of Personality and Social Psychology*, *91*(1), 188–204. https://doi.org/10.1037/0022-3514.91.1.188

Oyserman, D., Bybee, D., Terry, K., & Hart-Johnson, T. (2004). Possible selves as roadmaps. *Journal of Research in Personality*, *38*(2), 130–149. https://doi.org/10.1016/S0092-6566(03)00057-6

Oyserman, D., & Markus, H. (1990a). Possible selves in balance: Implications for delinquency. *Journal of Social Issues*, *46*(2), 141–157. https://doi.org/10.1111/j.1540-4560.1990.tb01927.x

Oyserman, D., & Markus, H. R. (1990b). Possible selves and delinquency. *Journal of Personality and Social Psychology*, *59*(1), 112–125. https://doi.org/10.1037/0022-3514.59.1.112

Patrick, A., & Borrego, M. (2016). A review of the literature relevant to engineering identity. *American Society of Engineering Education Annual Conference & Exposition*. https://doi.org/10.18260/p.26428

Paulsen, C. A., Cardella, M. E., Jones, T. R., & Wolsky, M. (2015). Informal pathways to engineering: Interim findings from a longitudinal study. *American Society for Engineering Education Annual Conference & Exposition*, 26.962.1–26.962.12. https://doi.org/10.18260/p.24299

President's Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future*. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf

President's Council of Advisors on Science and Technology. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering and mathematics*. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

Quintelier, E., Verhaegen, S., & Hooghe, M. (2014). The intergenerational transmission of European identity: The role of gender and discussion within families. *Journal of Common Market Studies*, *52*(5), 1103–1119. https://doi.org/10.1111/jcms.12129

Schildkraut, D. J. (2007). Defining American identity in the twenty-first century. *The Journal of Politics*, *69*(3), 597–615. https://doi.org/10.1017/cbo9780511761249.003

Schreuders, P. D., Mannon, S. E., & Rutherford, B. (2009). Pipeline or personal preference: Women in engineering. *European Journal of Engineering Education*, *34*(1), 97–112. https://doi.org/10.1080/03043790902721488

Smith, J. A., Flowers, P., & Larkin, M. (2009). *Interpretative phenomenological analysis: Theory, method and research* (1st ed.). Sage Publications.

Steffens, M. C., Jelenec, P., & Noack, P. (2010). On the leaky math pipeline: Comparing implicit math-gender stereotypes and math withdrawal in female and male children and adolescents. *Journal of Educational Psychology*, *102*(4), 947–963. https://doi.org/10.1037/a0019920

STEM—Girl Scouts. (n.d.). Retrieved February 11, 2018, from http://www.girlscouts.org/en/our-program/our-program/stem.html

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Career choice: Planning early for careers in science. *Science*, *312*(5777), 1143–1144. https://doi.org/10.1126/science.1128690

The research agenda for the new discipline. (2006). *Journal of Engineering Education*, *95*(4), 259–261. https://doi.org/10.1002/j.2168-9830.2006.tb00900.x

Ufnar, J., Shepherd, V. L., & Chester, A. (2021). A survey of STEM outreach programs during the COVID-19 pandemic. *The Journal of STEM Outreach*, *4*(2). https://doi.org/10.15695/jstem/v4i2.13

Vagle, M. D. (2018). *Crafting phenomenological research* (2nd ed.). Routledge.

Vedder-Weiss, D., & Fortus, D. (2011). Adolescents' declining motivation to learn science: Inevitable or not? *Journal of Research in Science Teaching*, *48*(2), 199–216. https://doi.org/10.1002/tea.20398

Vieira, A., Carrieri, A. de P., Monteiro, P. R. R., & Roquete, F. F. (2017). Gender differences and professional identities in health and engineering. *Brazilian Administration Review*, *14*(1), 1–22. https://doi.org/10.1590/1807-7692bar2017160082

Vignoles, V. L., Schwartz, S. J., & Luyckx, K. (2011). Introduction: Toward an integrated view of identity. In *Handbook of identity theory and research* (Vol. 1, pp. 1–27). Springer. https://doi.org/10.1007/978-1-4419-7988-9

Wallwey, C., Clark, A., Sassi, M. S., Elmore, K., Kajfez, R. L., Mohammadi-Aragh, M. J., & Doty, A. N. (2020). Longitudinal memos investigating first year engineering pathways. *American Society for Engineering Education Annual Conference & Exposition*. https://doi.org/10.18260/1-2--34932

Wei, S. T., & Hill, T. W. (2018). An evaluation on engineering identity of K-12 youth using the engineering ambassador network (evaluation). *American Society for Engineering Education Annual Conference & Exposition*. https://doi.org/10.18260/1-2--29783

Zaretsky, S. (2018). *There are now more women in law school than ever before*. Above the Law. https://abovethelaw.com/2018/03/there-are-now-more-women-in-law-school-than-ever-before/

Appendix

Table 5
Pre-interview protocol.

	Base question	Sample follow-up questions
1	Please tell me about your drawing.	What is your engineer doing? Tell me a little bit about your engineer: What are they like? What are they good at? What are they not good at? What else do they do? What do they use to do their work? Who do they work with? How are you like this engineer? How are you different from this engineer?
2	What have you done before (in Girl Scouts, school, or some other activity) that is engineering?	How did you know this activity was engineering?
3	When you think about the future, what do you imagine becoming? *If they answer "I don't know":* What kind of things do you like learning about?	Why does that interest you? What qualities or characteristics make you a good fit for that? What steps will you need to take to get there?
4	What don't you want to become in the future? *If they answer "I don't know":* What kind of things do you not like learning about?	Why does this not interest you? What qualities or characteristics make you a not-good fit for that?
5	How would you feel if you became an engineer?	Is it something you think is likely? Why or why not? What characteristics make engineering a good/bad fit for you?
6	Those are all the questions I have. Is there anything else that you would like to share?	

Table 6
Post-interview protocol.

	Base question	Sample follow-up questions
1	Please tell me about your drawing.	What are you doing? Tell me a little bit about what it would be like to be this engineer: What skills would you need to do this job? What about you would make you good at this job? What about you would make doing this job hard for you? What else might you do? What kinds of tools might you use? Who might you work with? What steps would you have to take to become this engineer? Do you think it's likely? Why/why not? How would you feel if you became an engineer?
2	Let's look at the first drawing you did. How are these two drawings similar/different?	What kinds of things did you think about while drawing the second one vs the first?
3	Let's talk about the badge/Journey work. What surprised you the most what you learned? What surprised you the least?	Have you thought about engineering differently after the badge/Journey work? If so, what have you been thinking about? How was this similar/different than learning in other settings? (e.g., school, on your own, etc.)
4	Last time we talked, you said you wanted to be {X} and didn't want to be {Y}. Has anything changed with that?	How does engineering fit into that list?
5	Those are all the questions I have. Is there anything else that you would like to share?	