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Transitioning Pre-College Informal Engineering Education Experiences into the Virtual Environment

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Abstract

Informal STEM experiences have been identified as a critical element of the development of future scientists and engineers, who are needed to meet the growing technical demands of our society. However, the landscape of informal experiences irrevocably changed following the COVID-19 pandemic, as many opportunities for informal STEM experiences were forced online. The movement of these traditionally hands-on experiences online brought both challenges in implementation and opportunities for broadening access.

This paper provides recommendations for virtual informal STEM experiences based on a Girl Scout engineering badge experience which moved to a virtual environment following the start of the COVID-19 pandemic. The recommendations were developed from data gathered while transitioning the program online. Participant outcomes from the study are also included to provide additional details about the experience. Participant interviews and activity observations were analyzed to develop recommendations. Interviews and observations were analyzed to understand how choices made during the transition impacted participant's experiences and outcomes. Additionally, facilitator debriefs occurred after each participant interaction and were used to identify areas for improvement and develop recommendations. The recommendations generated from the analysis focus on how to transition an informal engineering experience into a completely virtual or hybrid environment.

The recommendations developed from this study include: 1.) Carefully craft your learning environment for participant success, 2.) Be flexible and adapt activities as needed, 3.) Create a supportive environment where struggle and failure are okay and 4.) Leverage your network to develop relationships with organizations you wish to partner with. These recommendations can be used to support engineering educators as they seek to transition historically in-person informal STEM experiences into virtual experiences and create new virtual experiences to broader participation. Virtual experiences can help expand access to engineering by creating programs which are accessible to participants who do not have these types of experiences available to them locally and are unable to travel to participate.

Keywords: informal engineering, pre-college, virtual, broadening participation

Introduction

In late 2019, a novel coronavirus emerged from the Hubei province in China. The disease caused by this virus, COVID-19, spread quickly, and on March 11, 2020, the World Health Organization (WHO) declared that COVID-19 had become a pandemic [1]. The COVID-19 pandemic drastically altered our day-to-day lives, including the educational landscape in the United States (US). Many universities transitioned to completely virtual learning for the remainder of the spring terms (e.g., [2], [3]), as did K-12 schools (e.g., [4]).

In addition, the landscape of informal STEM experiences in the US was drastically altered by the pandemic. As communities entered periods of "lock down" [5], traditionally in-person, hands-on informal STEM experiences were forced to shut down operations fully or adapt and develop virtual opportunities for their participants. While this transition from in-person to virtual settings created many challenges, such as how to convert activities that were designed to be completed in a group and in person to an individual, virtual activity, it also afforded opportunities to increase access to engineering. This unintended consequence opened new doors in engineering education that remained relatively closed to many children. Moving forward, virtual programs may allow for pre-college students, especially those who may not have access to engineering in any other areas of their lives, to be exposed to engineering. There is potential in this new access to truly broaden participation in engineering and ultimately increase the engineering workforce.

In this article, we share our experiences transitioning one traditionally in-person informal experience, a Girl Scout engineering badge, into a virtual one. This experience, including participant outcomes and badge workshop observations were used to develop recommendations for others who wish to transition their informal engineering experiences into virtual experiences. While the pandemic was a catalyst for moving programs online, we believe that even after the COVID-19 pandemic ends, being able to offer effective informal STEM experiences in a virtual setting is vital. Such programming can support increased access for students who may not typically be exposed to engineering in their communities or in formal learning settings and possibly broaden participation in engineering in traditionally underrepresented groups.

Background

In the last two decades, there have been increased opportunities for pre-colleges students to engage in engineering, both in formal, or in-classroom, (e.g., [6], [7]) and informal, or out-of-classroom (e.g., [8]–[12]) settings. However, the impacts of these informal settings on participants are not well understood [13], as informal settings only represent about 25% of the studies on pre-college engineering education [14]. Further complicating our understanding of informal engineering experiences, informal STEM experiences are offered by a wide range of organizations. More than half of informal STEM experiences are offered by universities and colleges (26%) and non-profit organizations (25%), though other common settings include national youth organizations (8%), museums and science centers (15%) and K-12 school districts (12%) [15]. The programs offered by these organizations vary widely in contact hours, participant demographics, staff background, and program offerings [15]. However, previous research has indicated that many of these programs provide a successful foundation for STEM interest and later STEM careers. For example, STEM camps and STEM after-school clubs have been shown to increase interest in STEM careers ([16], [17]) and have been identified as a factor that influence later self-efficacy in STEM [18] and STEM career choice [19].

National youth organizations, which are part of the informal STEM learning networks, may provide an important setting for students to explore the engineering field. More specifically, some of these organization may be a prime location to engage groups that are traditionally underrepresented in engineering. For example, approximately 67% of national youth organizations specifically target girls in their programs, much higher than the national average of 43% [15]. Given the persistent gender imbalance in the engineering field [20], organizations which target girls, such as the Girl Scouts, may be critical partners to better understanding the impacts of these informal experiences on girls. However, very little research has been done on the impact of experiences within national youth organization, though a few studies have identified them as impactful settings for engaging in STEM (e.g., [21], [22]). If engineering experiences and their impacts within these contexts were better understood, they could perhaps be leveraged to improve women's representation in engineering. Subsequently, the focal informal engineering experiences for this manuscript occurred in the Girl Scouts.

In 2017 the Girl Scouts rolled out engineering experiences [23], part of a pledge to bring 2.5 million girls into the STEM pipeline by 2025 [24], and has continued to release additional experiences each subsequent summer ([25]–[27]). These experiences included both engineering Journeys and badges [23], with content developed for girls across their membership age range (K-12). The engineering experiences available through Girl Scouts range from more general experiences focused on engineering design thinking (e.g., [28]) to more specific experiences, like the *Programming Robots* badge [29] that the Girl Scout troops in our population worked on. Additional experiences are available, such as those focused on automotive engineering, mechanical engineering, and coding [30]. Some experiences, including the engineering design thinking and robotics experiences, are currently available for all age ranges, though several experiences, including the automotive engineering and mechanical engineering experiences are only available for younger Girl Scouts [30]. The Girl Scouts provides a wide range of opportunities for girls of any age to engage in engineering experiences and explore the field.

Context

In spring 2020, we were engaged in the pilot portion of a study focusing on the impact of participating in Girl Scout engineering experiences on middle school girl's engineering identity. This study, which will be described in more detail below, was framed using Possible Selves Theory (PST) [31], and data collection included pre- and post-interviews, as well as participant observations. Three Girl Scout troops had been recruited, and meetings had been scheduled for the pilot, though data collection had not yet begun. Then on March 23, 2020, Ohio, where the research was occurring, issued a "stay-at-home" order due to the COVID-19 pandemic [32]. This order was not lifted until late May 2020 [33], though local health officials continued to urge citizens to stay at home. During this time, we worked to adapt the in-person badge curriculum to a virtual environment to continue my research and support these young girls.

Two of the three troops originally recruited for the pilot study agreed to take part in the revised virtual pilot study, and the third troop asked to be considered for the future full study. Both troops in the pilot study were Cadette Girl Scout troops (Grades 6-8) from a suburb of a large Midwestern city. Both troops chose the Cadette badge *Programming Robots* [29] to complete. The badge curriculum indicates that the activities should take place over the course of two 90-minute meetings; however, at the request of both troop leaders, the badge activities were modified to occur during one two-hour meeting, as the number of meetings they had remaining in the year was limited. This required adjustment to the engineering badge curriculum by identifying elements that participants could complete outside of the badge workshop time. Some badge activities include: building a basic circuit, prototyping a robot, working in groups to develop algorithms, and discussion regarding the activities and concepts covered in the badge curriculum. Both badge workshops occurred on Zoom, a web-based video conferencing platform, with all participants and members of the research team joining from their own homes. Two members of the research team attended each badge workshop, with one leading the badge activities from the Girl Scout curriculum and the other acting as an observer, focusing on how the girls interacted with each other, the materials and with the facilitation team. To facilitate the badge workshop, a supply kit was provided to each participant, either by mailing it directly to her or by providing kits to the troop leader who delivered them to the participants. Participants were asked to provide common household supplies, such as tape, paper, and pencil, but all other materials were provided to them. The materials there were supplied were identified by asking three people to review the total badge activity supply list and indicate what of the material they had readily available in their home. If all three people did not have the item in their home, it was included in the participant's kit to ensure the girls had the needed materials to complete the badge.

While we were optimistic and thought the full study may be able to be completed in person, as the months went on, it became apparent that online learning was the new mode of engagement during the pandemic. As such, the full study also occurred in a virtual environment approximately five months after the pilot. For the full study, two mixed-age Girl Scout troops, both consisting of Junior and Cadette Girl Scouts (Grade 4-8) were recruited and both chose the Cadette *Programming Robots* badge [29]. Though the research team joined both troops remotely, one troop, referred to as "the hybrid troop" met in person, and the second, referred to as "the online troop", met completely online via Zoom. Both troops held two 90-minute meetings. As with the pilot study, materials were provided to the participants. These materials were largely the same as the materials provided in the pilot study, though some additional materials were added as activities were adjusted. For example, the badge curriculum originally included an activity where participants wrote an algorithm to navigate a "room", which was to be set up on a chess board so that the "room" could be easily altered. While many participants had a gameboard at home, the original approach to the activity did not work well for several reasons, including the difficulty participants had sharing their "room" and difficulty in helping participants troubleshoot the algorithm they had developed. Therefore, an apartment floorplan, printed on cardstock, was included as the basis for this algorithm activity. This allowed for easier troubleshooting and eliminated a bottleneck in the activity of setting up a "room".

The hybrid troop consisted of 16 Junior and Cadette Girl Scouts, nine of whom participated in the identity study. Approximately 10-12 troop members attended each meeting. For the first meeting, the troop met together outdoors, where several picnic tables had been put together to make one long table. The troop leader placed a laptop at one end of tables, and the research team joined the troop meeting via Zoom. However, the meeting was held in the evening, so toward the end of the meeting it became very difficult for the research team to see the participants, and presumably, more difficult for the participants to complete activities due to decreasing light levels. For the second meeting, the troop met at the troop leader's home and were split into two groups, one in the kitchen and one in the dining room, with a laptop in each room. Again, the research team led the meeting via Zoom.

The online troop consisted of nine Junior and Cadette Girl Scouts, six of whom participated in the identity study. For both meetings, this troop met via Zoom set up by their troop leader. They had been meeting via Zoom throughout the pandemic and several participants mentioned that they were in all-online school, so these participants were very familiar with video-conferencing platforms. Participants joined from their own homes. Individual kits for all activities were made for each troop member and delivered to the troop leader who ensured that all troop members received a kit.

Methods

As discussed previously, two data sources (interviews and observations) were gathered for this study. The data was analyzed to provide insight into the impact of the participant's engineering identity and understanding of engineering [34]. Additionally, the data was analyzed to seek to better understand the impact of the choices that were made in the transition from an in-person activity to a virtual one, as well as any additional insight regarding supportive and effective online informal engineering experiences that could be gleaned from the data. Research methods and data analysis are described below, as is the process through which the recommendations for virtual informal engineering experiences were developed.

Interviews

Interviews were conducted with the study participants, a total of 15 girls (i.e., all of the troop members who consented to be part of the identity study), before and after the badge workshops. Before each interview, the participants were asked to complete the Draw-an-Engineer Test (DAET) [35], though the second instance of the DAET was slightly modified to ask participants to draw what it would be like if they were engineers. The DAET images were used to facilitate portions of the interview. The lead author acted as the main interviewer, and a second researcher who had also been trained in the interview protocol attended to take notes. These interviews generally focused on how the participants view engineers, engineering, and themselves in relation to engineers and engineering, though also included questions about the learning environment by asking participants to reflect on the similarities and differences between learning in Girl Scouts and learning in another setting. The interviews were semi-structured in nature to allow for follow-up questions as needed [36].

The interviews were transcribed, deidentified, coded using *a priori* codes developed from PST and codes developed directly from the data. Then, structured memos ([37], [38]) were developed for each participant and the memos were examined for themes regarding how participants viewed engineering, their identity related to engineering [39] and the learning environment and overall badge experience. The patterns which emerged from this portion of the data was used to inform the recommendations for online informal experiences shared here. For more details on the analysis of the interviews, please see our work focused on the impacts of the experience on the participants [34].

Observations

While the lead author lead the badge activities, a second member of the research team conducted observations throughout the meeting [40]. These observations focused on how participants interacted with each other, how they interacted with the materials, how they interacted with the research team, and how they discussed engineering. We could only observe those troop members who agreed to take part in the overall identity development study, though these represented most of the girls at each meeting. The observer was primarily a non-participant observer, as we were aiming to limit the influence of our presence on the participants [41]. Following each observation period, the observation field notes were summarized for later analysis [36]. These summaries were developed through conversation between the lead author and the observer and focused not only on *what* had happened but also reflecting on the implications of the experience for the participants [42]. In addition to discussions regarding the observations themselves, these debriefing sessions included discussion of the activities that had occurred during that meeting. Here, the focus was on identifying what had gone well, what had not gone well, and how the activities could be improved for future implementations of the experience.

The observation notes and memos were reviewed while developing the structured memo for each participant. A summary of the observations for each participant was developed and included as much detail as could be gleaned from the notes. Unfortunately, because of the nature of both the hybrid and the online environments, these observations were more generic than we had initially hoped. In the online troop, the troop members did not interact with each other much, if at all, and some participants left their camera off during the badge meetings. In the hybrid troop meetings, we had an incredibly limited view from one or two laptops, and it was often difficult to identify who was speaking. However, the observations were used to contextualize the differences between the two interviews. Additionally, the observation notes and memos were heavily reviewed and discussed to inform the recommendations discussed below.

Recommendation Development

Following the data analysis described above, recommendations were developed from the data. This occurred through a process of reading the data analysis, reflection on my own experiences and the data analysis, and consultation with other researchers. We initially drafted the recommendation and then shared these drafts with the researchers who had acted as observers during the badge meetings and note takers during the interviews. Feedback was provided, and the recommendations were adjusted accordingly.

Limitations

These recommendations were developed from a small number of instances with one informal experience, so this may limit the wider applicability of the recommendations. However, to limit the impact of this, the recommendations were, wherever possible, grounded within literature regarding learning and are the result of collaboration between several researchers with experience in informal engineering education. As these recommendations are derived from the outcomes of this study, but situated within the wider body of learning literature, we believe that these recommendations are applicable in many informal engineering experiences.

Additionally, informal engineering experiences vary widely in content, contact hours, host organizations, and many other factors [15]. This study, and the recommendations derived from it, occurred within one informal experience, that of a Girl Scout engineering badge. Though it is likely that these recommendations will be applicable to other experiences with similar structures, the recommendations are likely to be less applicable in informal experiences which have significantly different structures. However, based on our experience with informal engineering settings, we believe the basic structure of engaging participants with the engineering content via a set of hands-on activities is a relatively common approach, indicating that these recommendations are likely applicable to many programs.

Data and Recommendations

In this section, we share pertinent data from the study, which informed the recommendations, as well as the recommendations themselves. Three recommendations were derived from the interview and observation analysis and are described here. A fourth recommendation was developed from our experiences outside of the study setting and is described in the following section.

Recommendation 1

When comparing the observation data between the two troops, we noted significant difference in the apparent engagement with the activities. In the online troop, of the six participants, we observed that most of them showed active engagement with the material by answering questions, sharing the artifacts that they had created and interacting with the facilitators. In comparison, we struggled to engage the hybrid troop and often had to ask questions multiple times before we would get responses from participants. We also observed participants engaged in off-task behavior such as unrelated conversations and running around the meeting space. We believe these differing levels of engagement resulted from the two different set ups and how participants perceived the facilitator's accessibility. In the online troop's meeting, participants were all able to hear and interact with the facilitators without the barriers of distance from the microphone or speaker. This did not appear to be the case with the hybrid troop, as we often had difficulty hearing and understanding participants who were seated further away from the laptop, and we were often asked to repeat myself.

Across both troops, we found it very difficult to troubleshoot when participants struggled with activities. This was particularly apparent during the "build a sensor" activity, where participants made a simple circuit from copper tape, a watch battery, and an LED. This circuit was built on an index card and was a basic "pressure sensor", as the circuit was closed, illuminating the LED, by folding the edge of the index card over. While many participants successfully assembled these "sensors" with limited difficulty, there were a few participants who struggled to build the circuit. Troubleshooting something at the scale of an index card over Zoom was very difficult, and we observed frustration from many participants who had problems with their circuit. Unfortunately, in the hybrid troop, while the troop leaders were there in person, they did not have sufficient knowledge or experience with the activity to be effective troubleshooters.

Additionally, when analyzing the interview data, we found that across both troops, participants generally showed an improved understanding of engineering [34]. This occurred both in the NGSS engineering design components [43] which they described and in a lower rate of stereotypical drawings of engineering in the post-interview. However, the troop's differed in their engineering identity outcomes. Most participants had no engineering future selves at the beginning of the study, and many had future selves related to their current hobbies or interests. However, in the post-interviews, the only participants who showed growth in their engineering identity were in the online troop [34]. Several participants noted in their post-interviews that they viewed engineering as "boring" and "complicated". We hypothesize that these views of engineering being "boring" and "complicated" at least partially relate to the environment of the hybrid troop's meeting, discussed above. The environment of the hybrid's troop meeting appeared to make it difficult for participants to engage on two fronts. First, some participants had difficulty understanding what was being asked of them, often due to their distance from the laptop or other conversations occurring around them. This may have resulted in participants feeling that engineering is very complicated, as the activities had to be explained several times. Second, because the activities were often explained many times, activities often took much longer than anticipated. This extended period of time for each activity may have resulted in participants thinking that the badge activities, and thus engineering, was boring. Together, this data led to our first recommendation that will be discussed further below: ***Carefully craft your learning environment to reduce barriers for participant success.***

Recommendation 2

As described above, after each meeting, the observer and the lead author discussed what had gone well with activities, what had not, and what could be adjusted. This was particularly important during the pilot phase of the study, as the transition from a curriculum that was designed for in-person implementation to an online environment was first occurring. In the meeting with the first troop during the pilot study, we attempted to replicate the activities in the leader's guide exactly. However, while some activities, like discussions about the activities and engineering concepts, worked well in an on-line environment, others, such as the algorithm development activity did not work as well. To determine what activities were working well, we looked for signs that participants were engaging with the materials, that they understood what was being asked of them, and that the outcomes of the activities were in line with the goals of the activity. For some activities, it was clear that they did not translate well into the online environment. For example, one activity was to take the sensor participants built (the circuit described above) and incorporate it into a "box model" of a robot, with the goal of prototyping how to implement the sensor within a robot. However, we observed that the goals and purpose of the activity were unclear to the pilot troops, as many participants simply continued to play with the circuit and could not identify how they would use it. We adjusted the activity to include a demonstration of how the participants might implement the sensor in the robot model, however, confusion continued. This is illustrated by several participants in the hybrid troop spent the time creating a reindeer, with the LED from the pressure sensor acting as the reindeer's nose, rather than implementing it as a functional sensor. This activity would need to continue to be refined in future implementations of this experience, and perhaps even replaced with an activity which covers the same concepts of testing and prototyping but in a format that works better for the setting.

Other activities, such as having the participants develop and test an algorithm, were more successfully adapted. Initially, participants were asked to develop an algorithm for a robotic vacuum cleaner to navigate a room, and there was to be a communal chess board with "obstacles" set up which could be used to test their algorithm. However, in the pilot study we found that even for participants who had a chess board at home, this was a confusing and difficult task. In the full study, we first had the participants write an algorithm for making a peanut butter and jelly sandwich. They then tested their algorithm by reading it aloud, as the lead author made the sandwich according to their direction. Next, we provided an apartment floor plan and asked them to write an algorithm for the robot vacuum cleaner. This allowed the participants to first develop an understanding of the test and iteration aspect to programming, before attempting to develop a more complicated algorithm. Because of these experiences, our second recommendation is: ***Be flexible and adapt activities as needed, while focusing on the learning outcomes for the activities***

Recommendation 3

In the post-interview, we asked participants to reflect on what it is like to learn in Girl Scouts versus what it like to learn in other settings such as school. The participants gave a wide range of responses, including some participants who felt it was the same. However, another pattern emerged. Several participants indicated that they were more comfortable learning in Girl Scouts because they were not afraid to admit when they were struggling or needed help. Hannah, a fifth grader from the online troop, said,

> *Oh, the Girl Scouts I feel more confident in what I'm doing and I know that if I did it wrong, it's not really going to matter because I can just do it over again. But in school, I'm not as confident or know people as much, and if I get something wrong or it's either like, okay, or it's going to go to my grade…mostly because people at Girl Scouts are best*

friends to me but the people at school, like I have friends at school, but most of the people, like if I go in front of the class to say something, it feels very pressured to do that

Similarly, Ava, a sixth grader from the hybrid troop said, *"Girl Scouts because everyone could help each other out, you can always fix it."* These responses, and other similar ones, indicated that, for some participants, the community that they were experiencing this engineering content in was an important part of how comfortable they felt trying new things. These comments led to our third recommendation, which will be further discussed below, is: ***Seek to develop a supportive environment, where it is okay to ask for help, struggle, and fail.***

Discussion of Recommendations

In this section, we further expand upon the three recommendations developed from the data, and present a fourth recommendation, developed from our experience sharing this study in other forums.

Recommendation 1: Carefully craft your learning environment to reduce barriers for participant success

As can be seen from the study results, ensuring that the learning environment is conducive to participant success is critical. When comparing the online troop's and the hybrid troop's experiences, it seems that the completely online experience had slightly better outcomes than the hybrid troop. In the online troop, we observed participants who were more engaged with the materials and saw a slight impact in some troop members engineering possible selves. However, we do not believe that this indicates that online is somehow superior to a hybrid setting. Instead, with better planning, the hybrid setting could have been as successful as the online. It is important to consider what barriers may arise from the chosen set-up and take steps to mitigate them. Each situation will likely be unique, but some considerations while planning a virtual informal STEM experience are:

- <u>Technology and/or sound:</u> this is particularly important for hybrid settings, though clearly communicating what technology participants need to fully participate in an online experience is also important. Ensure that the technology set up, particularly speakers and microphones, will be sufficient to effectively communicate with the participants. Ensure that the set-up is tested, if possible, to ensure that it will work as desired.
- <u>On-site adults:</u> particularly with hybrid settings, though often with virtual setting as well, pre-college students have adults nearby who may be able to help. Consider, what, if any support you need from them and communicate this clearly. Consider what training adults may need to provide that support. For example, are there activities that the participants may need help troubleshooting? Supplies that need to be available but are not provided?
- <u>Participant interaction:</u> consider how participants will interact with you. This may include participants asking questions, answering questions, or getting help with an activity. For an online experience, should participants use the chat feature? Should they just speak up? What activities might need troubleshooting? What troubleshooting can you do remotely? Similar consideration should be made for a hybrid experience.
- <u>Supplies:</u> consider what supplies will be needed for the activities and how participants will obtain them. We recommend providing as many of the supplies as you can. This will reduce the likelihood of a participant being unable to complete an activity because they do not have the correct supplies and helps reduce barriers to participation for participants of low socio-economic status. If you are requesting that participants provide "common

household materials" ask several people to review your list for participant supplied materials, to ensure that the materials are commonly found in a variety of people's homes. Secondly, consider how any supplies that you are providing will get to the participants. Be sure to account for transit time and delays if supplies are being mailed.

By reducing barriers, ranging from financial concerns (providing supplies) to technology concerns (discuss and test beforehand), participants can more easily engage with the materials, and participation and access to the engineering field may be increased.

Recommendation 2: Be flexible and adapt activities as needed, while focusing on the learning outcomes for the activities

Some activities which are often used in informal STEM experiences simply will not translate well to an online environment, for a range of reasons such as the supplies needed, the activity difficulty, or the ability to troubleshoot the activity. When adjusting activities from an in-person environment to a virtual environment, consider the concept of "backwards design" (e.g., [44]). In backwards design, activities are constructed first by establishing the goal (or learning outcome), and then working backwards to identify the activities needed to achieve that goal. For example, as described above, originally the badge activities suggested setting up a "room" on a chess board and having the participants write an algorithm for a vacuum robot to navigate the "room". However, this proved difficult for participants to understand, set up, and share with the group in a virtual environment. To adjust this activity, the learning objective was first identified: practice writing, testing, and revising an algorithm. Then, a range of activities was considered to allow participants to practice algorithm development. Ultimately, we settled on the "write an algorithm to make a peanut butter and jelly sandwich" because it allowed for a participant's algorithm to be tested very visibly, through demonstration. Some considerations to make when adjusting an activity for a virtual environment:

- <u>Learning objective(s)</u>: Identify the activity's goal. In informal settings, these may not be as clear as they may be in a formal learning setting, so some educated guesses may need to be made. For some activities, there may be multiple goals or "hidden" goals, where one activity serves as the basis for another. Be sure to consider not only the individual activity, but how the activity fits into the larger picture.
- <u>Alternate activity formats:</u> Virtual, especially completely online, formats bring opportunities to leverage technology in ways that are more difficult to implement in a traditional in-person format. Consider what videos, simulations, or games might be available online to achieve similar learning goals to the hands-on activities. For example, several participants in my study mentioned code.org [45] as an online resource that they had previously used for coding. These, or other online resources, can be used to expose participants to important concepts. Outside of online resources, consider pre-made kits (e.g., [12]) that may alleviate concerns regarding supplies.
- <u>Consider what activities might be better accomplished before or after the event:</u> Especially in a scenario where the meetings are time limited, consider asking participants to complete part of the activity after your meeting, or come to a meeting with something already completed. For example, during the pilot phase of the study, leaders asked to reduce the length of the meeting. To accomplish this, we asked participants to continue to iterate on their "box model" robot and robot vacuum algorithm after the meeting. This allowed for the meeting time to focus on introducing activities and concepts.

By employing alternate activities, an informal experience can be effectively transitioned into a virtual environment and provide a better experience for participants than trying to directly reproduce what would be done in person.

Recommendation 3: Seek to develop a supportive environment, where it is okay to ask for help, struggle and fail

As the participants in this study indicated, their Girl Scout troop provided an environment where it was okay to struggle, ask for help, and even fail. Consider how your learning environment can support struggle, seeking help, and failure. This is true in both online and in-person settings but may need to be more carefully cultivated in virtual environments where it may be difficult to see others who struggling in some way with the activities. Failure and struggle are an important part of both engineering design and scientific research, so modeling this can help present a realistic image of the field. Additionally, research on learning indicates that failure and struggle, or what Brown, Roedinger and McDaniel [46] call "effortful learning", supports student's learning and retention. Similarly, the work of Carol Dweck [47] highlights the importance of what she calls a "growth mindset", that what students are capable of is not determined by nature, but is determined by effort and responses to struggle and failure. Clearly, being comfortable with struggle and failure plays an important role in successful learning. However, as Hannah noted above, students often feel uncomfortable with failure, especially in formal learning settings, so it may take work for participants to feel comfortable with the struggles and failures of "normal" engineering.

This may be done more easily in established groups, like Girl Scout troops, as it may already be part of the group's culture. However, the following strategies may be leveraged to create a supportive environment:

- <u>Model supportive behavior in response to failure</u>: Encourage participants as they work through activities and model responding to struggles positively. Additionally, consider setting explicit norms regarding how participant's respond to each other's struggles and failures. You may consider sharing a book or video to illustrate how struggles and failure as a normal and important part of engineering, for example the children's book *Rosie Revere, Engineer* [48] describes failure this way: "with each perfect failure, they all stand and cheer, but none quite as proudly as Rosie Revere" (p. 15). Additionally, the movie *Big Hero 6* [49] includes a depiction of the numerous iterations that Tadashi, a main character, goes through to develop the robot he has been developing, Baymax. These, and other, resources, can be used to illustrate struggle, failure, and persistence in the context of engineering.
- <u>Explicitly communicate that struggles and failure are normal</u>: Often there is an implicit or explicit message that if something is hard, you must not be good enough at it [46]. For many, especially those who exhibit what Carol Dweck calls a "fixed mindset" [47], this means that students will dismiss something that is difficult as "not for them". However, Dweck's work indicates that by simply communicating how learning works and that challenges are an important part of learning, some students adopt a "growth mindset", which supports their learning through challenges.

Supporting participants through struggles and seeking to establish a growth mindset can help participants feel more successful in the engineering activities, but also may serve to support their learning in other realms of their lives.

Recommendation 4: Leverage your network and build relationship within organizations you wish to partner with

When sharing our work in various forums, the question we are most frequently asked is: *How were you able to engage the Girl Scout troops you worked with?* The short answer is that the lead author had an existing, long-term relationship with the local Girl Scout council and was able to access troops through her connections developed from those relationships. However, by leveraging social and professional networks, it is likely that you can reach the appropriate person at an organization, even without a pre-existing relationship. West, Kajfez, and Riter said, [50] "*It is sometimes necessary to look beyond professional networks in order to achieve the partnership that is desired."* (p.3). This may be achieved by looking within your social network, or by first seeking out opportunities as a volunteer within the organization. It is especially important to build relationships within an organization if you are considering conducting research in that setting, as people outside of academia are often unfamiliar with research outside of a medical setting so establishing trust and relationships first is essential. Even if the only goal is to provide experiences based in your expertise, first establishing relationships is likely to aid in ensuring that the appropriate participants are aware of the opportunity and make it possible to implement an impactful program.

Future Work

In the future, these recommendations should be tested by using them to intentionally design and pilot an informal experience within the Girl Scout setting. This is particularly true in a hybrid setting. We believe that hybrid settings can provide opportunities for participants to interact and support each other, however, as was shown in this situation, hybrid setting also offer additional challenges that online settings do not. Because there was no hybrid setting in the pilot phase, recommendations regarding the set up a hybrid setting have not yet been put into practice. Secondly, these recommendations should be applied to developing programs for participants of different characteristics, to better understand how the recommendations may need to be adjusted to be widely applicable. This may include programs with different populations, or programs which use which use different approaches to exploring STEM topics. Finally, recommendations should be implemented in other settings, outside of the Girl Scouts, to develop virtual informal experiences. Using these experiences, the recommendations can then evolve to be applicable to a wider range of settings. Over time, a set of best practices for engaging pre-college students in virtual informal engineering experiences should be developed, to support a wide range of accessible informal experiences.

Conclusions

Informal engineering experiences are an important way for pre-colleges students to engage with engineering in a meaningful way and may help meet the ever-growing need for engineers in the United States. However, many students have limited access to these influential programs. Virtual programs, though initially driven by the rising COVID-19 pandemic, provide opportunities to expand access to engineering, even int the future. The recommendations presented here are based on my successes and struggles in transitioning a traditionally in-person informal engineering experience into a virtual experience. These recommendations may be helpful to others seeking to accomplish similar transitions. By leveraging what has been learned in the pandemic, we may be able to expand access in engineering to traditionally underrepresented populations and help impact participation in engineering among these populations.

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