# Gatekeepers to Science and Engineering

*Informal Science and Engineering Educator Roles in Positioning and Recognizing Girls' Identity Performances*

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## Abstract

Girls and women are underrepresented in many science and engineering fields. The gender stereotypes associated with who belongs in science and engineering (SE) disciplines are one of the reasons for this underrepresentation. Research on formal SE classrooms has shown how these stereotypes negatively affect educators' positioning and recognition of girls as science and engineering learners. Informal SE education (ISEE) programs have shown promise for confronting stereotypes and creating environments for girls to develop SE identities based on improved interest and sense of belonging in SE. Yet, few studies have focused on the role of educators in these ISEE spaces both in terms of how they recognize girls but also the ways they position girls to perform their SE identities. To address this gap, we examine how ISE educators in two summer camps enact and implement activities that engage girls in the "doing of science" and the "doing of engineering". Educators built on the inherent social contexts of the respective camps and gave girls the opportunity to negotiate their roles as scientists and engineers. We observed the girls engaging in collective sensemaking, initially modeled by the educators and eventually led by the girls, which mirrors the collaborative work of scientists and engineers. We also highlight a continuous feedback loop wherein educator positioning and recognition elicited SE performances and resulted in more opportunities for girls to engage in the practices of science and engineering and build their SE identity development.

**Key Words:** Science and Engineering Identity, Educator Positioning, Girls, Informal Science and Engineering Education

## Introduction

In the United States, calls to reform science, technology, engineering, and mathematics (STEM) education have focused on building the STEM workforce through science education (National Research Council [NRC], 2011; 2012; 2015). K-12 science education reforms call for the preparation of all students to become proficient in science (i.e., sensemaking to construct and refine explanations about phenomena; Hutchinson & Hammer, 2010) and engineering (i.e., iteratively designing and refining solutions to problems; Cunningham & Kelly, 2017; NGSS Lead States, 2013; NRC, 2012). To address the needs of our society, there have also been calls to attend to marginalized populations that have historically been underrepresented in STEM, including girls, women, and people of color (Bell et al., 2017; National Science Foundation [NSF], 2021).

Women hold less than one-third of STEM jobs despite representing 50% of the US population (NSF, 2021; US Census Bureau, 2019). The underrepresentation of women has multiple causes, but one of these is the decline in science and engineering (SE) interest due to perceptions that these fields do not relate to their lives and because they do not see a place to succeed in these male dominated fields (Authors, XXXX; Joseph et al., 2017; King & Pringle, 2018). The stereotypes that portray SE as unwelcoming and irrelevant begin as early as elementary school (Archer et al., 2017; Carlone et al., 2014; Tan et al., 2013). In order for girls and women to become and stay interested in SE and see themselves as potential scientists and engineers, they need to develop SE identities during their formative years (Allen & Eisenhart, 2017; Kang et al., 2019).

We define SE identity as one's interest and sense of belonging in SE based on their growing sense of competence developed through opportunities to perform and to be recognized for doing the work of scientists and engineers (Calabrese Barton et al., 2013; Carlone & Johnson, 2007; Carlone et al., 2014). This definition is a combination of Carlone and Johnson's conception of science identity as a continuous cycle of performance and recognition of science competences spurred on by interest, along with the resulting sense of belonging that has been highlighted by Calabrese Barton et al. (2013). Recognition has been found to be a valuable piece to SE identity formation and has traditionally been studied as coming from formal classroom teachers and family members (Authors, XXXX; Carlone et al., 2014). But for many girls, stereotypes associated with gender and race affect their perceptions of who belongs in SE. These same stereotypes lead teachers to position girls differently or not at all and/or recognize the SE competence of boys in more supportive ways than girls (Archer et al., 2015; Collins, 2018). This in turn makes it more difficult for girls to develop SE identities.

## Literature Review

Both formal and informal educators are often the first gatekeepers to SE for youth because they are the adults who introduce youth to science and engineering and what constitutes the *doing of science* and/or the *doing of engineering*. Research has indicated that participation in informal science and engineering education (ISEE) programs in elementary and middle school, can positively influence girls' and women's SE identity development (Chan et al., 2020; Ferguson & Martin-Dunlop, 2021). ISEE spaces can offer participating youth opportunities to see the relevance of SE to their lives and to engage in authentic SE practices, increase their interest in SE, and make them feel like they belong (Calabrese Barton et al., 2013; Carlone et al., 2015; Kim et al., 2018; Pattison et al., 2020). Consequently, educators have the power to strengthen or diminish girls' SE identities through their positioning and recognition of these performances, consequently, shaping how they are viewed by others and how they view themselves (Calabrese Barton et al., 2013; Carlone et al., 2015; Davies & Harré, 1999; Tan et al., 2013).

Research that has focused on girls' SE identity work in ISEE spaces has typically referenced positioning from the perspective of the girls – i.e., how girls are positioned by the norms and structures of the space and how they position themselves within these spaces (for science see, Calabrese Barton et al., 2013; Carlone et al., 2015; for engineering see, Pattison et al., 2020). When these authors reference the role of the educator in girls' identity work, they usually do so in the context of recognition. These studies help us to understand girls' SE identity development but call for a stronger understanding of how ISE educators' positioning and recognition influence girls' performances (i.e., their identity work). Our study addresses this gap.

## Conceptual Framework: Positioning and Recognition in the Ways of Doing Science and Doing Engineering

SE identity development is both a reflection of how one perceives, positions, and aligns oneself within a discipline, and how one is perceived and recognized by meaningful others (Calabrese Barton et al., 2013; Carlone & Johnson, 2007; Collins, 2018). In order for girls to identify as science and/or engineering people, they must have opportunities to do the work of scientists and engineers (Calabrese Barton et al., 2013). Consequently, it is important define educator positioning and recognition. Both positioning and recognition occur within social contexts like ISEE spaces where educators and youth are negotiating roles (van Langenhove & Harre, 1999). During these negotiations, educators can position youth as scientists through opportunities wherein youth are producing and assessing knowledge (Berland et al., 2015; NGSS Lead States, 2013; NRC, 2012) and as engineers through opportunities to design, build, and test prototypes to assess the success of their design solution (Cunningham & Kelly, 2017; NGSS Lead States, 2013; NRC, 2012). Inherent in positioning are dynamics of power in which those doing the positioning – educators as gatekeepers – can have a stronger influence than others based on their perceived authority. Educators can position certain youth and ways of knowing as more important based on the types of activities they choose to implement in their class/programs, the design of the activity, the framing of the activities, and how and who they acknowledge during the activity (Archer et al., 2015; Bell et al., 2017; Berland et al., 2016; Collins, 2018).

Recognition is intricately linked to positioning (Calabrese Barton et al., 2013; Carlone et al., 2015; Tan et al., 2013). How one is recognized and by whom for their SE performance in a positioning event can support or constrain one's views of themselves as a scientist or engineer, how they choose to act in future SE events, and how they interact with others during those SE events. The purpose of our study is to understand how ISE educators' positioning and recognition during moments of doing science and engineering create opportunities for girls' SE identity work in a science summer camp and an engineering summer camp. This study was guided by the following research questions:

1. How do educators position girls during tasks to engage them in the work

of scientists and engineers?

2. What are the types of recognition that occur during these moments?

# Methods

To answer our research questions, we chose a case study approach (Creswell & Poth, 2018). Initially, the two cases were two all-girls middle school summer camps held the summer of 2018: (1) the Marine Science Camp (MSC) which had a science focus and (2) the Explorations in Engineering (EiE) camp which had an engineering focus. (The names of programs and all people have been changed to pseudonyms, and the study has been approved by our institution's Human Subjects Board). Both camps were free to participants and advertised to students living in the nearby area. The programs both had the term "girls" in the title of the camp. On the application, individuals could self-select their gender category among options of male, female, and would prefer to specify. All participants in both of these camps selected "female". The purpose of both camps was to support girls, as underrepresented groups in STEM: (1) to engage in science and engineering activities; (2) to expose participants to female role models in science and engineering; and (3) to develop their confidence and competence in science and engineering. The participating girls were asked to complete video diaries on the first and last day of the program that lasted between 15 and 55 seconds. On the first day they were asked why they signed up for the camp and what career they were most interested in. On the last day, they were asked what their favorite part of the camp was and if the camp had changed their career interest. For the MSC camp, the pre and post video diaries show that of the 20 campers, 14 (70%) said that the camp increased their interest in SE careers and the remaining six (30%) said that the camp maintained their interest in marine science. For the EiE camp, the pre and post video diaries show that of the eight campers, three (38%) said that the camp increased their interest in SE careers, five (64%) said the camp maintained their interest in engineering or STEM. This improved interest and maintenance of interest were indicators of improved science identity or at least maintained interest during the camp.

To better understand what was occurring to create these changes and/or maintain interest in the girls we examined 40 hours of video footage from both camps. The cameras were placed at locations on the edges of the rooms to capture the entire space and to avoid being in the way of camp activities. The first author was a participant observer at the MSC and the second author was a participant observer at the EiE camp. As participant observers, we jotted down notes related to the physical structure of the room, educator positioning, girls' performances, and the recognition these performances received.

To better describe the positioning and recognition of educators we chose to select a science and an engineering activity (from launch to debrief) from each camp wherein the girls were engaged in the doing of science and the doing of engineering respectively. To define activities as doing of science and doing of engineering, we were guided by Tekkumru-Kisa and her colleagues (2015; 2020) concept of "tasks", ambiguous activities that ask students to use disciplinary knowledge while engaging in disciplinary practices (Tekkumru-Kisa et al., 2020). The implementation of rigorous science or engineering activities (i.e., tasks), positions girls to take on the role of scientists and engineers and engage in disciplinary ways of doing, which is crucial for identity development (Calabrese Barton et al., 2013). In their work, Tekkumru-Kisa and her colleagues defined tasks – which we refer to as activities - as meaningful chunks of classroom activities (from introduction to debrief) that focus the researcher on the structure of the task and the quality of teaching and learning enacted during the task. Examining these activities from introduction to debrief helped us to identify and focus on educators' positioning and recognition during moments wherein students were engaging in cognitively demanding work that promoted learning and identity development, which we define as the disciplinary ways of doing science and/or engineering (Nasir, 2002; Tekkumru-Kisa et al., 2015; 2020). We selected one activity from each camp that served as an exemplary case because it was an example of doing science or engineering and because of the amount of dialogue present within the activity that provided the discourse between the girls and the educator(s) allowing us to answer our research questions.

## Identifying Activities Aligned with the Doing of Science and Engineering

There were three stages to our analysis that led to our final case selection. During Stage 1, we used our notes from the observations, and the video recordings to select activities where we observed girls "doing the work" of scientists (Berland et al., 2016) or engineers (Cunningham & Kelly, 2017). Activities that did not fall into this category were those in which students were engaged in getting to know each other, mentor presentations, and field trips/tours. The final list and description of the identified science/engineering activities can be found in Table 1.

Table 1: Description of Doing Science/Engineering Activities

| Marine Science Camp | | |
|---|---|---|
| Name of Activity | Description | IQA Scores (Rigor of Design/ Launch/Implementation/Discussion) |
| 1. Core Sampling | Day 1. Girls were given a "core sample" (e.g., sand and clay) made by the educator and asked to identify layers. | (4/4/4/5) |
| 2. Who Messed with the Nest | Day 1. Girls were asked to solve the mystery of who messed with the sea turtle nest by collecting data from the site. | (4/4/4/4) |

| | | |
|---|---|---|
| 3. Floating Rainbow | Day 2. Girls used the density to create a “rainbow” in a glass (distinct layers of water using heat, cold, salt, and food coloring). | (4/4/4/4) |
| 4. Snook Water Needs | Day 2. Girls tested three water samples for various parameters to determine which area would be the best nursery for baby snook. | (4/4/4/4) |
| 5. Animal Stranding | Day 3. Girls were given data (e.g., lab results, pictures) about a dolphin or manatee stranding and asked to determine cause. | (5/5/5/5) |
| 6. Calculating Wave Speed | Day 4. Girls solved for speed, given the frequency and wavelength. The compared their answer to the computer simulation. | (2/2/2/NA) |
| 7. Dough Creatures | Day 4. Girls were asked to use circuits to design a marine animal (real or imagined) that had multiple LED bulbs that lit up. | (2/2/1/NA) |
| 8. Shark Movement | Day 4. Girls were given accelerometer shark data movements and asked to infer/present what their shark was doing. | (5/5/5/4) |
| 9. Communicating a Prototype | Day 5. In pairs, girls designed a written prototype and then worked to create prototypes based on other pairs’ descriptions. | (5/5/5/4) |
| Explorations in Engineering Camp | | |
| 1. Grab-n-Go | Day 1. Girls built a mechanical arm that could be operated by one person to pick up and return a weighted paper cup that was one foot away without damaging the arm. | (5/5/5/4) |

| | | |
|---|---|---|
| 2. Deep Sea Diver | Day 1. Girls engaged in the engineering process by designing, building and testing a “diver” that was neutrally buoyant in a column of water. | (5/5/5/4) |
| 3. Wetlands Band | Day 1. Girls created an instrument from everyday materials (e.g., sticks, balloons, and rubber bands) that sounded like a wetland animal of their choosing. | (5/4/3/0) |
| 4. Dough Creatures | Day 2. Girls created simple circuit creatures that would light up using dough, wires, lights and batteries. | (5/5/4/2) |
| 5. Locker Lights | Day 2. Girls created a locker decoration that used a simple circuit using common materials such as tape and paper. | (5/5/5/NA) |
| 6. Twirling in the Breeze | Day 2.Girls created a device that would act as an anemometer and to come up with a way to use that device to measure wind speed. | (5/4/4/3) |

During Stage 2, we examined the activities in more detail using the Instructional Quality Assessment – Science Observation Rubric (IQA-SOR; Tekkumru-Kisa et al., 2020) to determine how each educator positioned youth in the doing of science/engineering. According to the IQA-SOR, activities are divided into four phases: Phase 1: design, the potential of the activity for intellectual work; Phase 2: launch, the educator’s launch of the intellectual work; Phase 3: implementation of students’ actual intellectual work that occurs during the enactment of the activity; and Phase 4: debrief, the discussion in the whole group debrief wherein students’ explanations of their sensemaking are grounded in their work and evident through their arguments. We assessed the rigor of design for each activity based on our position as participant observers. For Phases 2 through 4, we assessed the rigor by examining the launch and debrief phases in our videos focusing on the educators’ positioning of doing science and/or engineering identity work and the youths’ related performances along with the educators’ recognition of these identity work performances. The enactment of activities in both camps began with an introduction (or launch), which was followed by the implementation in small groups and then a whole group debrief facilitated by the educator.

Using the IQA-SOR we analyzed videos and assigned numbers to each phase based on the cognitive rigor, ranging from 0 to 5. Higher IQA-SOR scores or more rigorous tasks (4 and 5) align with the ways of doing science and engineering and lower scores (0 to 3) align with more traditional ways of learning that are not considered the doing of SE (i.e., rote memorization, following steps to an expected outcome) (Berland et al., 2016). We rated the four phases of each camp activity separately and then met to watch the video segments together to determine if our rationale and observations made sense to the other author. We reached consensus on these ratings after discussion and we used the consensus IQA-SOR scores to determine which activities to examine more thoroughly in our Stage 3 analysis. These activities and their IQA-SOR scores (nine activities in the MSC and the six activities in the EiE camp) can be found in Table 1.

## Analysis of Positioning, Performance, and Recognition

During Stage 3 of our analysis, we focused on the launch and debrief sections of the activities. These sections provided rich opportunities to explore the educators' positioning of the girls as SE people and the resulting performances and recognition events that occurred therein. Due to the locations of our cameras, we were not able to capture conversations at individual tables (in small groups) during the implementation phase but the whole group debrief could be captured giving us a reliable source of data to derive conclusions on recognition. We admit that recognition does occur and influence SE identity work in small groups, however, we were not able to capture those conversations. To guide our analysis, we developed codes based on each iteration of analysis. Initially, we started with three broad parent codes: educator's positioning for the doing of SE; SE performance by youth, and SE recognition by educators. We used the NGSS' and others' definitions (Berland et al., 2016; Cunningham & Kelly, 2017) of doing science and engineering (e.g., clarifying what counts as data, sensemaking, communicating your explanation). Our code book can be found in Table 2.

Table 2: Code book

| Codes | Descriptions |
|---|---|
| Positioning for | **Science fact inside content knowledge:** factual content learned in the camp<br><br>**Science fact outside content knowledge:** factual content outside of camp<br><br>**Epistemological knowledge inside camp:** describing how scientists and engineers do their work learned inside camp<br><br>**Epistemological knowledge outside camp:** describing how scientists and engineers do their work learned outside camp<br><br>**Inclusive positioning:** when the educator gives girls the opportunity to respond as a group (thumbs up/thumbs down) or gives a wait time for more girls to raise their hands and intentionally calls on girls who have not been vocal<br><br>**Clarifying what counts as data:** youth are positioned to plan and carry out (collecting data) an investigation |

| | |
|---|---|
| Performance as | **Factual response** (single word answers or answers without discussion of how or why)<br><br>**Epistemological knowledge response** (youth explain their reasoning)<br><br>**Sensemaking:** youth analyze and interpret data, active engagement in the uncertainty as they are figuring out a problem, making connections, brainstorming, using data to improve on a design<br><br>**Communicating your explanation:** youth verbally make sense of the phenomenon by explaining how and why something works and demonstrating prototypes<br><br>**Application to the real world:** youth give recommendations based on their understanding of the problem at hand (extrapolate out from the immediate scenario) |
| Recognition forms | **Positive affirmation (e.g., '**great job')<br><br>**Repeating of answers**<br><br>**Building on the ideas** (following up by asking girls to sensemake about their idea/answer)<br><br>**Inclusive recognition** (when the educator refers to girls as engineers or scientists, which tells them they are valued and recognized as STEM people) |

Throughout the analysis process we met to discuss our interpretations and ideas. We challenged each other's interpretations and suggested alternatives by providing evidence from our data sources. To highlight the educator positioning and recognition we have chosen to present our results as two comparative cases. The cases consist of an exemplary activity from launch to debrief from each camp. By using this format, we are able to present an in-depth examination of educator positioning and recognition that illustrates the complex issues bounded by the disciplinary context of each camp (Creswell & Poth, 2018; Miles et al., 2014).

## Setting and Participants

**Marine Science Camp (MSC) Learning Environment.** The MSC met daily from 9 am to 4 pm across five days at a marine research facility. There were two main educators, but our chosen case only includes one, Miss Angstrom. She is a white woman with experience working in museums and other ISEE programs. Twenty girls participated in the program, all of whom were from the local area. Table 3 includes the demographics of this camp

Table 3: Marine Science Camp

| | Percent | N (20) |
|---|---|---|
| *Race and Ethnicity* | | |
| American Indian or Alaska Native | 5.0% | 1 |

| | | |
|---|---|---|
| Asian | 5.0% | 1 |
| Black or African American | 5.0% | 1 |
| White | 70.0% | 14 |
| Hispanic or Latino/a | 20.0% | 4 |
| Other | 0.0% | 0 |
| *Gender* | | |
| Female | 100% | 20 |
| *Academic Information* | | |
| Currently Enrolled in Honors Classes | 60.0% | 12 |
| 6th Grade | 42.1% | 8 |
| 7th Grade | 36.8% | 7 |
| 8th Grade | 15.8% | 3 |
| 9th Grade | 5.3% | 1 |

**Explorations in Engineering (EiE) Camp Learning Environment.** EiE was a two-day camp that met from 9 am to 6 pm. The two educators were Miss Litre, a white undergraduate woman, and Miss Bohr, a Latina educator. Twenty-three girls participated from the local area. The demographics for the participating girls can be found in Table 4.

Table 4: Explorations in Engineering

| | Percent | N (23) |
|---|---|---|
| *Race and Ethnicity* | | |
| American Indian or Alaska Native | 4.3% | 1 |
| Asian | 21.7% | 5 |
| Black or African American | 8.7% | 2 |
| White | 30.4% | 7 |
| Hispanic or Latino/a | 34.8% | 8 |
| Other | 8.7% | 2 |
| *Gender* | | |
| Female | 100.0% | 23 |
| *Academic Information* | | |
| Currently Enrolled in Honors Classes | 73.9% | 17 |
| 6th Grade | 30.4% | 7 |
| 7th Grade | 52.2% | 12 |
| 8th Grade | 17.4% | 4 |

# Results

The goal of our study was to determine how educators' position and recognize girls during activities that are meant to engage them in the work of scientists and engineers. The girls in both camps either increased or maintained their interest in SE which is one metric for SE identity development. The educators played a crucial role in both camps because they positioned the girls for identity work through the design phase of each SE activity, their launch of the activity, and their facilitation of the discourse during the debrief. This section presents an exemplary activity from the MSC, followed by an exemplary activity from the EiE camp so that the reader can see the structure and educator positioning along with our coding analysis.

## Marine Science Camp Animal Stranding Activity

For the MSC, we chose to focus on the Animal Stranding activity. This activity occurred on the third day of the camp. It tied together a number of experiences and skills from the previous days. For example, on the first day, the girls visited the bone room at the Marine Lab where they met, Dr. Gwen, a marine biologist who investigates strandings on the nearby beaches – dead marine animals that wash up on shore. She is often asked to visit the site of a death to determine its cause in case there are steps that the local law enforcement or community can do to reduce further incidents. The Animal Stranding activity was framed as figuring out an uncertain phenomenon (Tekkumru-Kisa et al., 2020) because the girls were asked to determine what data they needed and then analyze that data to come up with a possible explanation of how their animal died. They did not know nor could they be exactly certain of the cause.

Miss Angstrom was the lead teacher for the activity. During the activity, the girls worked in small groups to determine the cause of death for their animal using evidence from case files and then presented their findings to the group in a mock interview by the local newscaster (Miss Angstrom). Miss Angstrom began the activity by showing the girls a PowerPoint highlighting marine biologists, since biology was the theme for this day. She asked the girls if they knew what type of career each woman pictured had. This positioned the girls for outside science foundational knowledge at first. She then positioned them for outside camp epistemological knowledge by broadening the concept of what counts as science when she asked:

> Miss Angstrom: Does anyone have any fish tanks at home? [hands go up indicating yes] So you have to be really aware of the water quality and the health and the nutrition of your animals within that tank. So, you're being a Marine biologist. Anyone in here like to fish? [hands go up] So you are learning about the environment, you're being a Marine biologist. If anyone's interested in filmography or photography underwater, you have to know some of the behaviors of these animals to know when you're gonna get the best shot. So, you have to have a little Marine biology background. Environmental law. I know a couple of you want to be lawyers, right? If you want to do environmental law, you need to have that science background too.

In this statement, Miss Angstrom was connecting the girls outside interests to science while also calling them scientists. She broke down stereotypes associated with what counts as science. We identified these moments as inclusive recognition because Miss Angstrom positioned all the girls to feel like they belonged and could be part of the work of scientists. In this example, she demonstrated the value that each girl's interest had, even those that might not be considered science by traditional Western standards.

Then Miss Angstrom launched (introduced) the activity by asking them about strandings, a concept that they had learned about on the first day of camp:

> Miss Angstrom: What program at the Marine Lab is Dr. Gwen responsible for? Do you remember?
>
> Peggy: The strandings program.
>
> Miss Angstrom: Absolutely. Strandings investigation. And can you remind me what exactly that means? What is a stranding?
>
> Joan: It's basically the same thing as beaching. So when a shark or a whale gets too close to the shore, they wash up on the beach.

Here Miss Angstrom positioned them for inside foundational knowledge, again broadening the opportunity for girls to perform (answer questions) because they all had the shared experience of meeting the role model and learning about her work on the first day of camp. Miss Angstrom called on different girls each time to bring more girls into the conversation (inclusive positioning). She also inclusively positioned the girls to participate because they had all met Dr. Gwen.

Next, she guided the girls through a conversation about how to tell the difference between dolphins and manatees.

> Miss Angstrom: [picks up manatee skull and a small container with teeth in it], so this is a manatee skull. All right, I'm gonna bring it around. And here are some dolphin teeth in here. I want you to see the differences? All right. [walks to each table] What do manatees eat?
>
> Sara: They mostly eat vegetation
>
> Miss Angstrom: Yeah, they eat sea grass, right. And what do dolphins eat? we mentioned earlier [someone yells out fish] and yeah, so they do eat fish. Um, so animals that are carnivorous and eat other animals, have what kind of teeth? [someone yells out, very sharp]
>
> Miss Angstrom: Right, sharp or pointed right? And animals that eat vegetation and plant life, they have what kind of teeth? Flat, Right? We have kind of a mix of those two in our mouths because we are omnivores, we can eat whatever, we can choose to not eat certain things, but we're designed to eat whatever. So yes, we can tell a lot about the difference between them.

Here Miss Angstrom positioned the girls for sensemaking. Rather than simply asking how the shape of the animals' teeth were different, she asked them what food they eat. This allowed them to connect the form and function. As the girls answered, she built on these answers and connected them to the sensemaking form and function conversation. Although the girls' performances here were mainly science factual responses, later in this conversation, we saw how Miss Angstrom modeled sensemaking for them.

> Miss Angstrom: And what else does a dolphin have that a manatee doesn't?
>
> Joan: echolocation
>
> Miss Angstrom: Okay. Can we see that?
>
> Joan: no
>
> Miss Angstrom: That's true, but you can't see that. So if we were just looking at a dolphin and a Manatee, one has a dorsal fin, and one other thing?

Here Miss Angstrom positioned the girls for clarifying what counts as data, when one girl says "echolocation" she asked if that trait was observable for them with the tools on hand. Although Miss Angstrom was doing much of the sensemaking and clarifying what counts as data for the girls (recognizing building on idea), her cognitive work served as a model of the doing science (e.g., clarifying what counts as data and sensemaking) that she wanted the girls to engage in during their small group work.

After engaging the girls in observational differences between manatees and dolphins, she moved the girls on to a discussion of animal behavior so they could better interpret the evidence they would be given in their evidence packets.

> Miss Angstrom: Now these tails look a little bit strange. Can someone tell me what they think has happened or why these tails look so weird?
>
> Fely: maybe a boat
>
> Miss Angstrom: Yeah. Okay, so maybe a boat strike. Both these animals have big chunks out of their tail missing what else is going on?
>
> Rayna: maybe they got tangled in fishing net
>
> Miss Angstrom: Okay, so maybe they got tangled in a piece of fishing net and a piece of their tail might have come off. what's a natural predator of dolphins?
>
> Joan: sharks
>
> Miss Angstrom: So sometimes they get into a little bit of a fight. So all these things could have happened. Now with all that in mind, would you send someone out to assess the situation and see if these animals are okay? Thumbs up if you think yes [girls vote], thumbs down, if you think no [girls vote]. [Majority vote yes]. Okay. I want you to take a closer look at these tails. Do you see anything oozing blood? [multiple no's]. So, we might, if they were displaying a behavior that wasn't normal, you might send someone, but if they're just going about their day and doing their normal thing. They're all good. This is an old injury. And if they're still acting fine,

then they're good.

Dr. Gwen had referenced these types of injuries on Day 1. So, all of the girls had access to inside foundational knowledge related to injuries and therefore had an opportunity to answer. We again saw Miss Angstrom use inclusive positioning when she asked the girls to vote with a thumbs up or down. Here she was giving girls, who might not feel comfortable sharing or confidant in their answer, an opportunity to engage in the work of science - making claims based on evidence. Then she clarified what counted as data for them.

As she moved to the implementation of the activity, she gave each small group a puzzle for them to put together the bones of their animal (i.e., a dolphin or a manatee). The girls began the implementation by completing their puzzle, identifying their animal, and then obtaining a folder with more evidence related to their specific case (e.g., pictures, description of the animal when it was found). Some of these descriptions included information on whether a necroscopy was completed or whether evidence was kept by the state. The girls then had to go to the various locations in the classroom to collect documents that represented lab results and analyze them at their tables. The authors observed the girls working together to solve their mammal mystery. Girls congregated at the evidence table, discussed questions and ideas with each other and Miss Angstrom. As Miss Angstrom went to each group she could be heard asking if they had a theory about what happened to their animal. She could also be heard asking them to explain the evidence they had that supported their theory. After 30 minutes, Miss Angstrom reminded the girls that the final step of the activity was to present their information to the group.

The debrief of this task was each group's presentation of the stranding investigations they participated in, which was designed to allow them to perform and engage in the work of scientists. Each small group presentation began with a mock interview with Miss Angstrom introducing herself as a newscaster and referring to the girls as the "Marine Lab stranding investigations team", and then asking them to explain what happened. Thereby positioning each group as scientists by asking them to communicate their explanation and recognizing each group for doing the work of scientists. And then positioning them as scientists again by asking them to explain what happened. During these group presentations we saw the girls performing sensemaking and the communication of their explanation. We provide one group presentation as an example below.

Miss Angstrom: This is Miss Angstrom with the evening news on channel six. I have with me the strandings investigation program from the Marine laboratory and they're going to clue us in to what happened recently in our neighborhood. Take it away.

Mary: Breaking news on case number four, one two, one with the dolphin that has been found dead on our beach. We have some information on that beach. Take it away, Peggy.

Miss Angstrom was inclusively recognizing them as doing the work of scientists by calling them members of the investigation program. The girls recognized each other as doing the work of scientists by turning to each other to explain.

Peggy: So the dolphin was found in the evening with a minor cut on his forehead. Um, or that we think might have been the results of a burn from a ship coming through where the oil got caught on fire.

Tricia: The dolphin had lung damage which is a result of the fire from the oil spill.

Joan: We think the cause of death was because of it breathing in too much smoke and ingesting too much oil. Here are the pictures of the dolphin stranding. [Lana is holding up pictures]

Initially, the girls were performing science facts by telling us that the dolphin had a scratch. Then they move into performing explanation by telling us how they thought the scratch occurred. Tricia performed the sensemaking for us by making the connection between lung damage and death. Miss Angstrom probed them for further sensemaking with her next question.

Miss Angstrom: And team, how can we avoid this in the future? What can we do to prevent a death like this?

Joan: So I've heard there's a solution and it was to put like a giant bag around the oil rigs. So the oil, when it leaks, it doesn't get out into the ocean.

Miss Angstrom: So better designed ships.

Peggy: and also, um, there could be, um, a substitute for oil. So something more eco-friendly,

Miss Angstrom: So clean energy. Well thank you very much. Give them a round of applause.

Here we saw Miss Angstrom asking them to apply what they had learned (positioning for application to the real world). Both Joan and Peggy provided outside foundational knowledge. And then Miss Angstrom recognized them by making the connection between the stranding and the application. She concluded the presentation by having the entire camp recognize the girls (positive affirmation).

The Animal Stranding activity was an exemplary case of the type of positioning, performance, and recognition that occurred during the MSC. Miss Angstrom designed an activity with a high degree of uncertainty where girls had to collect evidence to explain a scientific phenomenon thereby engaging in the work of doing science (Tekkumru-Kisa et al., 2019). During the launch phase Miss Angstrom positioned the girls so that they all could feel included by asking them about information they learned in the camp, thereby giving more girls an opportunity to perform their science knowledge. Then Miss Angstrom modeled the cognitive work of sensemaking and clarifying what counts as data as a way to model scientific behavior for the girls. Through her positioning, Miss Angstrom was also recognizing the girls by building on their ideas. Sometimes this included more talk from her but by the debrief phase the girls were doing the explanations and Miss Angstrom was recognizing them as doing science by calling them members of the Marine Investigation Team and by asking them shorter questions to elicit their performance of sensemaking. Miss Angstrom's use of inclusive positioning (giving more girls an opportunity to perform) and inclusive recognition (calling them scientists) gave girls multiple opportunities to engage in the doing of science and to be recognized for this work.

## Explorations in Engineering Grab-n-Go Activity

For the EiE camp, we chose to focus on the Grab-n-Go task, which occurred on the first day of the camp. The Grab-n-Go activity was led by Miss Bohr and supported by Miss Litre. During the activity, the girls were challenged to create a mechanical arm from a set of materials (e.g., rubber bands, tape, straws, and popsicle sticks) that could lift a weighted cup across a given distance and back. The challenge began with Miss Bohr introducing various concepts inherent to engineering, such as building and testing prototypes (NGSS Lead States, 2013). The girls then worked in groups to build, test, and revise a prototype of a mechanical arm that they had designed. They then shared this design by demonstrating their prototype in front of the whole group, picking up different weighted cups and moving them a predetermined distance with their constructed arm. Miss Bohr launched the activity by opening up a discussion about mechanical arms:

> Miss Bohr: How many of you have seen a mechanical arm anywhere. Like, on tv, at a museum. What stands out about those arms that you see?
>
> Allie: They don't have skin.
>
> Miss Bohr: They don't have skin. What are they used for?
>
> Student: To grab.
>
> Miss Bohr: To grab. Maddy?
>
> Maddy: Prosthetics
>
> Miss Bohr: Prosthetics.
>
> Jamine: Work purposes.
>
> Miss Bohr: Work purposes. Yes.

Miss Bohr positioned the girls for outside foundational content knowledge, by asking them if they had seen a mechanical arm, what stood out about mechanical arms, and what mechanical arms were used for. We saw evidence of inclusive positioning in this excerpt because Miss Bohr was providing opportunities for multiple girls to respond, calling on a different girl each time. This positioning and recognition helped the girls to see that they all possessed a common base of understanding and expertise that they could draw upon during the activity. However, unlike the Animal Stranding, Miss Bohr was relying on outside knowledge, privileging girls who might have more experience with engineering.

During the launch phase, Miss Bohr inclusively positioned the girls by highlighting the collaborative nature of engineering and soliciting multiple girls' ideas.

> Miss Bohr: Okay. What are some of the ways to go about this if you're working as a team?

Allie: Communicate.

Miss Bohr: Communicate. What does communication look like when you're brainstorming?

Harini: Actually speak to each other.

Miss Bohr: Actually speak to each other. Make sure everybody is listening. What are other really good things to do as a team?

Sierra: Brainstorm. Hear everybody's ideas. Like, not just one person.

Miss Bohr: Yes. Share everybody's ideas. All of us are at different levels so make sure if somebody is a little bit more, ah, quiet. Create space to really hear all their ideas. Our teams tend to be stronger when we hear all of the inputs. Right?

During this back and forth, we saw evidence of inclusive recognition because Miss Bohr recognized and built upon the girls' ideas of the collaborative nature of engineering.

After unpacking and discussing the importance of collaboration, Miss Bohr explained: "We [the educators] are not going to be able to tell you the answer because that's like no fun. But, we're able to be a sound board. If you have questions or something, we can try to help." This statement inclusively positioned the girls as the "engineers" during the activity and positioned the educators as "helpers" who could provide support but not "the answer". This changed the power dynamic in the space and empowered the girls to see themselves as the engineers. After this introduction, the girls engaged in the implementation phase of the activity. During this time, the authors observed the girls working together in small groups (2 to 3 girls per group), exploring and tinkering with the materials they were provided, negotiating their ideas for how they would use those materials to build their mechanical arm, building prototypes based on these ideas, testing out those prototypes, and making alterations to them based on those tests. Both Miss Bohr and Miss Litre moved around the room to see what each group was doing and answer their logistical questions about the requirements of the challenge; however, the groups were largely left alone to engage in the design process. Then Miss Bohr brought everyone together to demonstrate their prototypes during the debrief.

During the debrief, each group demonstrated their mechanical arm for the rest of the girls. Miss Bohr ensured that all girls had access (inclusive positioning) to these demonstrations saying: "Alright. So make sure all of your team members are around you. I'll move this chair so everyone can stand around. I want everybody from the rest of the teams to be able to see. That's the most important." This inclusive positioning continued throughout the debrief as the educators made sure that all groups showcased their device (performance). During these demonstrations, the girls were positioned by Miss Bohr in the ways of doing engineering including communicating explanations and sensemaking. Her positive affirmations during demonstrations and suggestions could be seen when she encouraged the girls who had successfully moved the cup across the finish line to "make their cup heavier or try to move it further down the table". Her encouragement to try something harder represents her recognition of the girls as doing the work of engineering and then positioning them to strengthen their skills by giving them a more challenging task.

We also saw examples of sensemaking and communicating explanations in the girls' mechanical arm demonstrations. In the following example, Miss Litre positioned a group by pressing them to explain (i.e., sensemake) how their devices work:

> Miss Litre: So what did all do to strengthen your design?
>
> Cailyn: So, at first we had string in it but then the string wasn't strong enough. So, instead, we just cut the string off and put it on a tooth brush thing.
>
> Miss Litre: Did you make it stronger with the toothbrush thing?
>
> Cailyn: [Shakes her head yes].
>
> Miss Litre: Good job.

In this excerpt, Miss Litre positioned the group to explain their sensemaking. Cailyn provided some explanation but Miss Litre finished the sensemaking for her. This was typical for the EiE camp, where sensemaking episodes were brief and mainly led by the educators rather than the girls.

The Grab-n-Go activity was an exemplar of the types of positioning, performance, and recognition that occurred during the EiE camp. Miss Bohr designed an activity with a high degree of uncertainty wherein the girls were challenged to engage in prototype design and testing collaboratively (Tekkumru-Kisa et al., 2019). During the launch, Miss Bohr positioned girls to share their outside foundational knowledge about mechanical arms and recognized them with positive affirmations. During the debrief phase, Miss Bohr and Miss Litre inclusively positioned all the girls to demonstrate their mechanical arm prototypes (communicate explanations). This positioning provided opportunities and resulted in performances of doing engineering as the girls communicated their explanations which included some sensemaking. Through these opportunities for performance and recognition, the educators were supporting the girls in their identity work by building a common foundation for the girls to reference. The educators helped the girls to feel like they belonged through their use of inclusive recognition and positioning.

# Discussion

Our presentation of these two cases: the Animal Stranding and Grab-n-Go activities, highlight the ways in which ISE educators position girls to engage in the work of scientists and engineers. The educators in both of these activities used similar strategies for positioning (e.g., positioning for content knowledge, epistemological knowledge, and the doing of SE) and recognition (e.g., positive affirmation, repeating answers, and building on ideas) which elicited doing science and engineering performances (e.g., factual knowledge, epistemological knowledge, clarifying what counts as data, sensemaking, and communicating an explanation). Despite research highlighting disciplinary differences between science and engineering instruction and engagement, we did not observe these differences in terms of educator positioning in either of these middle school ISEE spaces (Cunningham & Kelly, 2017; Hutchinson & Hammer, 2010). Rather the educators used similar types of positioning for both disciplines.

## Positioning Girls for Disciplinary Work

Although, the Grab-n-Go debrief had fewer examples of sensemaking by the girls, this is not necessarily an indication that one group of educators was better at positioning for sensemaking. The Animal Stranding activity occurred on the third day of camp, which gave the educators more time to create a space where girls were more comfortable sensemaking in front of the group. By focusing on positioning, we were able to see how educators built on the inherent social contexts of the respective camps (e.g., inclusive positioning, inside camp content, and epistemological knowledge) and gave girls the opportunity to negotiate their roles as women scientists and engineers (van Langenhove & Harre, 1999). These negotiations were evident in the launch and debriefs of the activities. During the launches, we saw the educators modeling the types of sensemaking that scientists and engineers do for the girls. The educators then provided space and asked questions that elicited more sensemaking from the girls during the debrief sections.

During the launches, we observed collective sensemaking that occurred in ways similar to the collaborative work of scientists and engineers (i.e., girls built upon and negotiated their roles and ideas together). This builds on previous research that has focused on the positioning of individual girls as they engage in science and/or engineering identity work– e.g., how individuals are positioned by the norms and structures of the space and how individuals position themselves within these spaces (Calabrese Barton et al., 2013; Carlone et al., 2015; Kim et al., 2018; Pattison et al., 2020). However, by focusing on educators' positioning and recognition within each case, we were able to see how these collective sensemaking norms and structures were demonstrated, fostered and taken up by the girls. Specifically, the girls met female role models who showed them that women could engage successfully in science and engineering identity work. Then the educators, reinforced these future selves through the positioning and recognition within the activities.

## The Role of Positioning and Recognition on SE Identity

Science and engineering disciplines are infused with social, cultural, and historical power domains that privilege canonical knowledge and practices that stem from Western male thought (Caraballo, 2019; Ryu et al., 2019). ISEE spaces, like formal science learning spaces are not immune from these power structures (Dawson et al., 2019). Educators play the role of gatekeepers, because educators hold the authority in the space (Calabrese Barton et al., 2013; Carlone et al., 2015; Tan et al., 2013). In both of our cases, we saw how educators were able to change the power differential and empower the girls to be recognized (and recognize themselves) as experts, negating stereotypes related to who participates in science and engineering. We saw this more often in the MSC than the EiE. However, we still saw evidence of educators' supporting girls in both activities to see themselves as scientists and engineers (Ryu et al., 2019).

Educators in these cases created space for foundational science and engineering content and epistemological knowledge. Although Miss Bohr relied more on outside content knowledge in the Grab-n-Go activity, this was because it was the first activity of the camp. She was creating an inside content foundation for the girls to reference. In the Animal Stranding activity, we see how Miss Angstrom built on camp experiences, rather than relying on the girls to bring their outside content and epistemological knowledge which would privilege those with more science capital (Archer et al., 2015). The educators' positioning for inside content knowledge created a space wherein the social norms of who belongs in science and engineering were challenged (Dawson et al., 2019). For instance, in the Animal Stranding activity, the girls had met a woman scientist who did the work that they engaged in. This introduction to Dr. Gwen provided a foundational experience for them to relate to and having a women talk to them, showed them it was possible for a woman to be successful doing the work. Miss Angstrom built on this foundation through her positioning and recognition, particularly in the inclusive positioning she utilized. Though we see evidence in both cases of this inclusive positioning by educators.

During the cases, the educators called on multiple girls, rather than privileging the same girls. The educators often had the girls voice their ideas in a group format (e.g., girls could vote on what they think the answer might be through thumbs up or thumbs down). This allowed girls who might not be as confident in their science and engineering skills (e.g., background knowledge) to pose an explanation. In addition, this positioning of all girls as scientists and engineers helped girls who might not see their salient identities as fitting with the social norms of the disciplines challenge these stereotypes and see themselves as scientists and engineers (Dawson et al., 2019). By engaging multiple girls and giving even those who are shy or less confident in their STEM skills opportunities to engage, the educators created a space for collective sensemaking where girls of multiple identities engaged in the disciplinary practices of science and engineering.

## Recognition of Disciplinary Work is Connected to Positioning

We observed that recognition and positioning were interconnected. Throughout both the launches and debriefs, the educators recognized the girls collectively as doing the work of scientists and engineers by actually calling them scientists and engineers or simply by saying that the girls had the knowledge that they needed to solve the uncertain and ambiguous tasks they were given. This type of inclusive recognition, changed the power dynamic within the space because the educators were showing that they were not the sole authority in the room. In addition, when educators were building on ideas, they were recognizing girls by asking them questions while simultaneously positioning them for disciplinary engagement (Bell et al., 2017; Berland et al., 2016). The girls were supported by the educators and each other as collaborators and experts in their disciplinary engagement, which showed them how they could resist the social norms of who does science and engineering (Dawson et al., 2019).

# Implications

Educators play an important role in helping girls develop stronger SE identities, however our understanding of this role has largely been focused on recognition (Calabrese Barton et al., 2013; Carlone et al., 2015; Kim et al., 2018; Pattison et al., 2020; Ryu et al., 2019). This study shows the connection between educators' positioning and recognition, demonstrating how educators can model the work of scientists and engineers (e.g., group sensemaking) and create opportunities for girls to engage in this work in ways that empower girls and challenge the stereotypes related to science and engineering. This study highlights that activities can be designed and facilitated in a way where girls can engage in relevant disciplinary identity work and see themselves as agents of scientific and engineering work in a relatively short time frame. The Grab-n-Go task occurred on the first day of the Engineering camp and yet within 45 minutes, the girls were engaging in the doing of engineering in a space where they were able to perform true disciplinary competences, like being willing to make mistakes and willingly sharing those mistakes in a group setting. Similarly, the Animal Stranding task built on shared knowledge and experiences from the camp to help the girls feel confident to engage in sensemaking and communicate their explanations like true scientists. The educators in both activities modeled the work of scientists and served as role models to the girls. Then the girls were given the opportunity to sensemake and construct disciplinary knowledge and be recognized as experts. Through these efforts, the educators supported the girls to create new and challenge existing social norms in science and engineering to see themselves as valuable members of these fields.

Although our study focused on ISE Educators, both formal and informal SE educators are often youth's first introduction to the disciplinary ways of doing science and engineering – gatekeepers to these disciplines and belongs within these disciplines. They translate SE practices and show girls what counts as SE performances and knowledge. Therefore, educators have an important influence on SE identity development. Their choices for and facilitation of activities and the ways they position girls for SE identity performance affect whether girls see themselves as scientists and engineers. In particular, girls may struggle to see themselves in male-dominated SE spaces. Our research provides evidence that educator positioning and recognition can create spaces for collective sensemaking where girls can share in the ownership of the production of knowledge. We must continue to critically examine the ways in which educators serve as allies to girls if we want SE disciplines to become diverse and inclusive and serve all members of society.

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