# Discussion Prompts to Support Family Engagement in Science:

## Talking about Astroengineering in Library-based Making Programs

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### ABSTRACT

Situated within a three-year design-based research project, this case study investigates how families learned about astroengineering. Eleven families (11 adults, 12 children) engaged in activities related to making a lunar rover in four library programs. To support their engagement in design tasks and engineering thinking, think-pair-share discussion prompts were employed between two- and four-times during workshops. Analyses of the implementation of the prompts by the astronomer leading the program and the family talk that resulted from the prompts found that parents were integral to supporting participation in the engineering activities. Youths often did not answer the astronomer's questions directly; instead, the parents re-voiced the prompts prior to the youths' engagement. The family prompts supported reflecting upon prior experiences, defining the design problem, and maintaining the activity flow.

### CCS CONCEPTS

• CCS → Applied computing → Education → Interactive learning environments

### KEYWORDS

Family learning; Libraries; Science education; Parent-child interactions; Design-based research



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### 1 INTRODUCTION

Our project investigates a research-developed model, which utilizes personally-relevant science learning [33], for family workshops held in libraries and museums. The project builds on existing formats for science activities and infuses these formats with research findings derived from parent-child learning studies, especially from the learning sciences. This work is inspired by research that shows that parents can guide youths' participation by generating interest and collaboratively building knowledge [8,35]. As such, our informal curriculum design relies on parents to guide social interactions in libraries based on prior work that has shown that children learn science more deeply in an informal setting when assisted by an adult [30]. However, because parents can miss opportunities to support children in scientific reasoning [15] by underestimating the challenges faced when learning new content, our design includes think-pair-share discussion prompts that serve as discussion guides for families.

Our work employs a discussion-based design for family learning implemented by science professionals facilitating programs in libraries in rural areas where parents and children engage with science and engineering practices together. This analysis focuses specifically on the utility of think-pair-share discussion prompts [25] that are applied to four astroengineering workshops held in rural libraries, which were taught by one astronomer (and former engineer), who was experienced in educational outreach.

### 1.1 Research Question

Our research question is: How do family think-pair-share discussion prompts support learners' sensemaking in astroengineering making programming held in libraries? To investigate this question, we used video analyses in a case study method to examine 23 learners' discourse and socio-technical interactions.

## 2 THEORETICAL FRAMEWORK

We bring together theory from three areas to support our investigation in this analysis: sensemaking talk and discussion prompts, constructionism, and science and engineering practices.

### 2.1 Science Talk as a Sensemaking in Informal Settings

In our study, conversations are both learning processes and learning outcomes [1,2,23]. In conversations, learners integrate knowledge, engage in sensemaking, and participate in science practices [1,24,35]. Sensemaking, also referred to as meaning making, occurs when people construct meaning by integrating prior and new knowledge. Sensemaking gives meaning to a new idea or object as learners create disciplinary and personal significance of what they are learning. Conversational sensemaking is often considered the primary learning process in informal settings [5].

*2.1.1 Sensemaking Talk Defined.* Our focus is on family sensemaking talk, which is defined as multiple conversational turns that have clear endings and beginnings, include at least two speakers from one family, involve discussing science or engineering content, and result in a new idea or understanding not present in the conversation [35]. Sensemaking is a dialogical process by which people create an explanation together in order to address a question, knowledge gap, or misunderstanding [28]. Consequently, to investigate sensemaking talk, we collected data consisting of video-based records of families' conversations in the libraries, which were collected with ethical considerations for research [12].

*2.1.2 Discussion Prompts to Facilitate Sensemaking Talk.* To facilitate families' sensemaking talk, our intervention incorporates think-pair-share discussion prompts [20]. In a think-pair-share discussion, families first think and talk in their parent-child pair, before sharing their ideas with the larger group. Prior work on discussion prompts highlights the potential to support peers to engage in more productive group discussion [20], facilitate knowledge building [21], and encourage reflection [11]. However, other studies have also illustrated that discussion prompts were often ignored by students or were addressed at a superficial level [14,16]. In our study, one astronomer provided think-pair-share discussion prompts to families throughout the workshop.

### 2.2 Constructionism

The design of our learning activity includes making [6,32] a lunar rover to understand how astronomers collect data. As such, we rely on constructionism, which connects a group's or individual's ability to build knowledge to the construction of an artifact. The learner's constructed artifact acts as a sensemaking object for the learner while also externalizing the learner's understandings [19,29]. In our intervention, the process of making [18,31] occurs as learners incorporate science and engineering understandings into their own moon rover artifacts.

### 2.3 Learning to be an Engineer by Doing Engineering

In the library workshops, families engaged in science and engineering practices that were developmentally-appropriate versions of the practices of working astronomers and aerospace engineers [10]. The lunar rover design involved disciplinary practices of problem definition; model development and use; conducting investigations; data analysis and interpretation; designing and selecting solutions; and arguing from evidence [27]. We adopted the Engineering is Elementary model (ask-imagine-plan-create-improve) [9] as a framework to organize the process of creating a lunar rover and its scientific instruments to families. Prior research provides guidelines for quality engineering education to develop curricula and teaching practices for K-12 audiences [26]; however, questions remain about how *families* can be supported to engage in engineering practices. Accordingly, we investigated how to design for family engagement in engineering practices with support from discussion prompts.

## 3 VIDEO-BASED CASE STUDY METHODOLOGY

Our study is a video-based case study of four workshops conducted as a part of a larger design-based research project, STEM Pillars [33]. In our study, each case was one family engaging in the astroengineering workshop.

The STEM Pillars curricula are developed to reflect science topics relevant to rural communities, including astroengineering, biomedical engineering, water quality, and weather forecasting. Each workshop is facilitated by a local scientist or engineer specializing in the topic at hand. The STEM Pillars programs are targeted toward families with children aged 5 to 10 years old.

### 3.1 Pedagogical Model of the STEM Pillars Workshops

Each STEM Pillars workshop follows the same basic structure, which includes adapted versions of project-based learning [4,7] and think-pair-share [25] discussion prompts. STEM experts received an hour of training (plus follow-up) and a workshop guide that outlined the details of the activity and included guidance on how to incorporate discussion prompts into the program.

The STEM Pillars programs are designed to be 60 to 75 minutes long. A STEM professional, experienced in outreach, facilitated each workshop. Each began with a personal narrative (story) of early experiences that were integral in his or her eventual pursuit of a STEM profession. The narrative included a description of their current job. The STEM professional then guided families through inquiry-based explorations organized by a driving question (Figure 1).

**Figure 1. Learners answered the driving question by designing the data collection instruments with littleBits components that will be placed on their lunar rovers.**

This case study is situated within iteration 3 of a design-based research project [33]. In iteration 3, discussion prompts were added to promote meaningful familial interaction within each topic. The inclusion of these prompts was based on an analysis of iterations 1 and 2 of our study, and our goal of creating space for parent-child sensemaking conversations.

### 3.2 Astroengineering Program Curriculum

The astroengineering workshop utilizes littleBits to help families make a lunar rover that carries scientific data collection instruments to the moon. LittleBits are electronic components, using magnetically-connected pieces, that facilitate prototyping and invention. Components include input sensors (i.e., temperature), outputs (i.e., lights, numbers), and power supplies. During the astroengineering workshop, children and parents used littleBits to create scientific instruments that could collect data as the rover explored the moon's surface. Families first engaged in free-form exploration of littleBits. Then, they worked in family teams (see Figure 2) to investigate the driving question: "How can aerospace engineers build space rovers that can carry an astronomer's tools?" Through interactions with littleBits and an astronomer, families made a mobile model of a lunar rover with scientific data collection instruments.

**Figure 2. A family building together (left), a learner putting data collection instruments together (center), and a family testing instruments on a simulated moon surface.**

### 3.3 Data Collection

The data were collected from 23 people who attended four workshops in rural and small-town libraries. The data includes ~ 11 hours of video. For each workshop, the team used 2-3 video cameras, 3-4 GoPro cameras, and multiple audio recorders. Photographs of families' lunar rovers were collected. The 11 families (11 adults and 12 children) that completed activities in English and stayed for the full hour at the first four library programs were included in this analysis

The average age of a child in this analysis was 8 years old. (Parental age was not collected.) More mothers attended the workshop in this dataset, with a distribution of 7 female and 4 male parents.

### 3.4 Data Analyses

*3.4.1 Analyzing the implementation of the prompts.* Our data analysis had two phases. First, we examined the delivery of prompts by our astronomy expert (William, pseudonym) to understand the implementation of the prompts. A 3-column matrix was created: one column was for designed prompts, a second column was for workshop transcripts of the implemented prompts, and the final column was for the families' responses. The team designed five prompts within the curriculum; however, only the first four were given to the families:

1. Take a few minutes to discuss with your family what you think astronomy is?

2. Discuss with your family what you noticed about littleBits. How could you use these tools to build a rover?
3. The first step, as an aerospace engineer, is to ask questions about the lunar environment to create a rover that withstands those conditions. What questions do you have about the moon? Please take a few minutes to discuss with your family.
4. Now talk with your family about how you would create a rover. Remember that there can be multiple ways to solve a problem. What would your invention look like?

*3.4.2 Analyzing families' discussions resulting from prompts.* Second, we examined the video-records of 11 families as individual cases to investigate if and how families' discussions were sparked by the prompts from the four library programs. In keeping with our case study methodology, for each family, we created an interpretive, narrative account of how the activities collaboratively unfolded. We asked if and when the parents re-voiced the prompts, and if and how the prompts supported the learners' sense-making and engineering practices.

The narrative accounts were 3-5 pages of text and images, which were organized into six sections. The first section was an overview of family discussion based on prompts. The next five sections were allocated to a transcription of the families' response to each of the designed prompts, which is the basis of the case study analyses. Researchers transcribed parent-child discussions, capturing the re-voicing of the prompts and discussion topics. Families' discussions were compared and contrasted within and across cases.

To ensure transcript validity and robustness of the interpretive accounts: (a) timestamps and screenshots from the video-records of learners' interactions were included so researchers could double-check video records, (b) the team held data sessions where the team read each author's interpretive, narrative account, and (c) every families' video was collaboratively viewed to update the accounts to reflect an interpretive consensus among the authors.

## 4 DATA AND RESULTS

Our analyses showed that think-pair-share discussion prompts supported learners' sensemaking in the astroengineering programs held in the four libraries. The analyses of the STEM professional's facilitation of the four workshops and of the narrative accounts of the eleven families illuminated the following patterns:

1. Across the four library workshop sessions, the facilitator did not consistently implement the prompts; only two to four were asked per session. All families answered at least one question together in their small group.
2. Parents supported the youths' participation in the engineering discussion. Youths often did not answer the STEM professional's questions directly; instead, most parents first re-voiced the prompts prior to the youths' engagement. Parents also maintained the flow of activities with reminding, focusing, and rephrasing.
3. The family prompts supported various kinds of learning conversations, including (a) reflections of prior experiences and knowledge and (b) defining the scientific problem their lunar rover could investigate.

### 4.1 Two to Four Prompts were Implemented

Across the first four workshops, while five discussion prompts were designed into the curriculum — only two to four questions were asked by the astronomer. All 11 families discussed at least one prompt; ten families discussed the first prompt. One family discussed only one prompt, seven families discussed two prompts, two families discussed three prompts, and one family discussed all four prompts asked.

### 4.2 Parents Supported the Youths' Sensemaking Talk

All families were successful in building a rover. We found that throughout the making experience, parents supported the youths' participation in the engineering discussion through re-voicing (repeating the question). In nine out of 11 families, the parent re-voiced the astronomer's questions at least once. In one case, the child re-voiced the question to the parent; in another case, neither family member repeated the question aloud. The re-voicing including repeating the astronomers' questions as well as rephrasing the astronomer's words into ideas that the youths could understand. The excerpt below demonstrates two ways families re-voiced: one was to repeat the question to focus the youths' attention and the other was to rephrase to encourage continued participation:

> Sadie (mother): Alright, so what do you want to study on the Moon? *[re-voicing expert's question]*
> Noah (age 5) and Emerson (age 8): ((no answer))
> Sadie: If you got to go to the Moon, what would you want to study? *[rephrasing expert's question]*
> Noah: Why the Moon has so many holes.

Noah and Emerson were similar to most other youths in our dataset; they did not answer the astronomer's questions directly. Instead, sensemaking conversations were facilitated by the parent first re-voicing the discussion prompts prior to the youths' engagement. Not only did most parents re-voice the astronomer's question once immediately after he spoke it aloud, as Sadie did above, but occasionally, the parents re-voiced the question later during a break in the making activity. Sometimes, the parents rephrased questions multiple times and ways, as shown in Sadie's second question. In this way, the parents served a key role to maintain the flow of the making activity by rephrasing.

### 4.3 Family Prompts Supported Two Kinds of Learning Conversations

Learning conversations were engendered by the think-pair-share discussion prompts in two manners: (a) elicitation of prior experiences and knowledge and (b) astronomy problem definition, which influenced the engineering solution designed.

*4.3.1 Eliciting Prior Experiences and Knowledge.* During our analysis, ten of the 11 families readily discussed their prior knowledge of astronomy in response to Prompt 1. In most cases, the parent called upon the child to provide examples; however, parents also suggested ideas. Importantly, parents reminded the youths of shared experiences. The transcript excerpts below demonstrate the patterns of reminding, suggesting, and eliciting ideas:

> William (expert): So, take a minute, talk among your families, talk with your kids and see if you can get an idea for what is astronomy? *[think-pair-share prompt]*
> Lu (mother): What do you think it is? *[re-voicing]*
> Penelope (age 8) : (no answer))
> Lu: Do you think it's stars, planets? *[suggesting]*
> Penelope: ((nods))
>
> Bob (dad): What do astronomers do? *[re-voicing]*
> Jaydon: Uhh
> Bob: What do they look at? *[rephrasing]*
> Jaydon: Uh, telescope!
>
> Mary: Like when we go out and look for meteors that we never seem to find, right? *[reminding]*
> Lance (age 10): Mhm.
> Mary: After doing that a couple of times, we would go out into the yard to see shooting stars. Watching the solar eclipse. *[reminding]*

Most often, parents first addressed the youths to start the conversation. Penelope was quiet at first, but Lu encouraged Penelope to speak by suggesting ideas, "Do you think it's stars, planets?". In the second excerpt, Bob supported Jaydon by re-voicing and rephrasing questions to focus on his astronomy knowledge. Mary reminded Lance of all the times they looked at astronomical phenomena in the sky from their yard.

For one family that did not discuss the first think-pair-share prompt, they did discuss prompts 2 and 3. We interpret their reaction as the discussion-based workshop was not expected, and so, this family took some time to understand a non-lecture-based program.

*4.3.2 Problem Definition and Engineering Design.* While unevenly delivered within the workshop, when families discussed Prompts 3 and 4, most often they used these prompts to discuss which problem they wanted to design astronomy instruments to address and how they wanted their design to unfold. The third prompt was both given verbally and was reiterated on a data collection sheet. This prompt facilitated parents' and children's attention on considering the measurements they wished to collect, which fostered discussions about their rover designs.

> June: ((looks at the design worksheet in Fig. 3)) Ooh, look at the temperature here. *[focusing]*
> Evie (age 7): Jeez!
> Jun: Look, it's also really bright. So, what do you want to study? *[re-voicing on the prompt]*
> Evie: How it can break.
> June: Break what?
> Evie: Like the stuff, so we can see about the eruption.
> June: When you go to the moon, you can look at the volcanic eruption?
> Evie: Yes!
> June: We'll have to find a way to study that. *[referring to the prompt.]* You have a lot of stuff connected there ((refers to the connected littleBits components)).

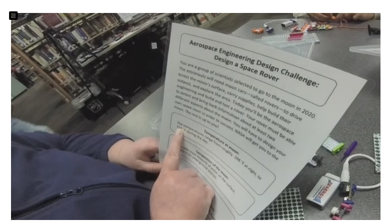


**Figure 3. Evie's mother June points to temperature information included with the design challenge.**

As this excerpt demonstrates, families used the prompts together to define the problem to be studied during the rover design challenge. In this example, June asked a series of clarifying questions to Evie that were grounded by the third prompt. This encouraged Evie to select light and temperature as measurements she wanted to collect from her scientific instruments. The family then moved onto the rover design process.

While the above excerpt between June and Evie is typical of learning conversations where the written design challenge served as a reference for parents when re-voicing the prompt, there was variation in our dataset. Other parent-child pairs selected the measurement type for their data collection instruments without the design challenge sheet. In a small number of cases, a parent constrained their child's choice to the one option listed on the design challenge sheet (i.e., temperature or light).

## 5 DISCUSSION

Our analysis of four STEM Pillars astronomy workshops suggests findings related to designing conversationally-oriented family learning in informal settings.

First, libraries and museums have to make choices about whether to create educational programs for the youths working alone or for the youths interacting with their parents. These results suggest an important role for parents in informal programs for youths aged 5-10: re-voicing questions to maintain sensemaking conservations. The youths in our study appeared reticent to directly answer an astronomer's questions; however, when the parents re-voiced and rephrased, conversations about astronomy were elicited. Parents also reminded youths of shared experiences and directed the youths attention back towards the prompts. The prior work in science learning has shown that when people are assigned or adopt roles in formal and informal settings, science learning is supported [17,34]. Our analyses add to this prior work by identifying a key role for parents. People's perceived roles in visiting informal spaces can also influence groups' experiences in out-of-school learning [13]. Our work suggests a conversational role for parents that may be important for designers of informal programs to consider.

Second, the STEM Pillars workshop intervention integrated a discussion-based pedagogy, think-pair-share, which was designed for school-based learning [25] into informal library curricula. Given the importance of learning conversations as sensemaking tools in informal settings [1,2,5,35], our conjecture was this discussion prompt would support families' meaning-making. The think-pair-share discussion prompts did support family conversations. Our case analyses illuminated the various ways in which the 11 families were successful in talking about their prior knowledge and/or their lunar rover designs. The case that did not discuss the first prompt suggests that some families may need support in engaging in this kind of pedagogic model. Given the limited sample size within our study, additional work is needed on how and when to best include discussion-based prompts; however, the utility of think-pair-share discussion prompts for supporting learning conversations in libraries is suggested by these initial analytical efforts.

Third, while the think-pair-share discussion prompt has been used by experienced science and engineering educators in higher education [3,22], we found that implementing the think-pair-share prompt in informal education was not necessarily easy for an astronomer new to teaching families. While our expert had presented planetarium shows and was experienced in outreach, the team was asking him to teach in a dialogical manner that was new to him. He implemented two to four of these prompts per workshop; next steps in our research include additional supports and time to focus on discussion-based pedagogies with our library facilitators.

Finally, our intervention focused specifically on engineering and scientific practices as families engaged in making with littleBits prototyping tools to collaborate on battery-powered data collection tools (i.e., sensors for temperature, light, pressure) that could fit on a model lunar rover. The families' engagement in engineering practices was facilitated through their interactions with prototyping and making materials [18,31] within the library environment. Given our study takes place in informal spaces, the activities and materials presented allowed for families to explore and make sense of science as they embodied their understandings into lunar rovers as representative artifacts. Additionally, given our inclusion of the EiE model (ask-imagine-plan-create-improve) [9], we found the think-pair-share prompts in our dataset most fully supported the early problem-definition phases of the EiE model (i.e., ask, imagine, plan). Given that the constructionist perspective includes not just making artifacts, but making artifacts for understanding [19,29], our study suggests the importance of discussion-based prompts to support constructionist pedagogies that utilize making; however, additional work is warranted on how and when to support creating and improving processes with discussion prompts.

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### Selection and Participation of Children

Participating libraries and museums advertised the program to their community with notice that researchers would be present with video cameras. Families self-selected to attend workshops but could attend without participating in the research. As families entered the workshop space, researchers guided parents through informed consent, obtaining written consent for study participation. Parents and children were told that they were participating in research and their involvement was optional. Following consent, researchers verbally assented children who were asked to participate and be recorded. Children were told that they did not have to answer any question nor participate in any activity. Children and parents were asked to consent / assent for their images to be shared in research publications such as this.

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