Gender Research on Adult-child Discussions within Informal Engineering Environments (GRADIENT): Early Findings

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Abstract

Exploring the gender differences in how children develop early interest and understanding in engineering can provide useful information for the ongoing efforts to address the low numbers of women who pursue engineering careers. By the time girls reach middle school, they are already much less likely to be interested in STEM careers than boys are, especially for fields that are math-intensive such as physics and engineering. This lack of interest has been connected to a narrow and often inaccurate view of the engineering profession and the perceived misalignment between what engineers do and what girls value in future careers.

Informal learning environments can play a pivotal role in inspiring today's youth to pursue careers in STEM. These contexts have been shown to be powerful and transformative settings in which young people can begin to cultivate lifelong interest in –and understanding of – a broad range of STEM topics. Moreover, informal learning environments often allow for parents and children to collaboratively engage in STEM learning, which may be particularly important in fields like engineering where parents have been shown to play a critical role in career choice.

The purpose of the Gender Research on Adult-child Discussions within Informal ENgineering environmenTs (GRADIENT) study is to explore gender differences in the development of early engineering interest and understanding. In particular, the project closely examines parent-child conversation within a range of informal engineering contexts that exist at the intersection of parents, children, and meaningful STEM learning. In this study we examine a pre-school program where parents and children can play with engineering-focused toys, a family-oriented engineering event for elementary students and their parents, and an engineering exhibit within a science museum. This paper focuses on the first setting, the pre-school program where parents and children play with toys to engage in engineering-related activities.

Drawing from the literature on both engineering education and informal science education, video-recordings from 30 daughter-parent dyads are analyzed for informal engineering learning in two ways. First, we investigate the parent-child discussions that occur during engineering activity using the lens of *Islands of Expertise*, a theory developed by Crowley and Jacobs (2002)[1] that suggests short instances of explanatory talk between parents and children within informal environments can form lasting linkages between interest and understanding over time. Second, we investigate specific engineering behaviours exhibited by the parent-child dyads. Preliminary findings suggest that both parents and children re-frame the design task that is given to them to add more context to the task. Iteration varies widely across the parent-child dyads, and examples of optimization also vary across the parent-child dyads. These findings provide insights into how what engineering thinking might look like for young children (aged 4-6 years) as well as insights into the types of engineering-related activities that may be engaging for young girls.

Introduction

Exploring the gender differences in how children develop early interest and understanding in engineering can provide useful information for the ongoing efforts to address the low numbers of women who pursue engineering careers. By the time girls reach middle school, they are already much less likely to be interested in STEM careers than boys are, especially for fields that are math-intensive such as physics and engineering.[2,3] This lack of interest has been connected to a narrow and often inaccurate view of the engineering profession and the perceived misalignment between what engineers do and what girls value in future careers. [4,5] At the same time, research suggests that many young women who do pursue engineering studies and engineering careers have a parent or another close family member who is an engineer.[6,7] However, other research suggests that even non-engineer parents can play a significant role in helping children to develop interest in and understanding of engineering.[8] Therefore, understanding the types of interactions that parents have with their children while engaged in engineering-related activities may provide invaluable insights into how children develop engineering interest and understanding.

Informal learning environments – ranging from everyday activities (such as conversations with family and friends) to designed environments (such as zoos, museums, and libraries) to afterschool and adult programs (such as hobby clubs or learning vacations) – provide a wealth of learning opportunities for people of all ages to pursue and cultivate interests on an immense spectrum of topics. Within these contexts, learners typically engage in open-ended activities that involve a high degree of "learner choice, low consequence assessment, and structures that build on the learners' motivations, culture, and competence" (p. 47).[9] Though an increasing number of studies have explored science learning in these settings[10-12,] leading educational researchers to recognize the untapped potential of exploring these environments, including Roy Pea, co-director of the Stanford Center for Innovations in Learning, who recently remarked about both the dearth of research on learning in informal contexts and the need to investigate them further at the 2011 Conference on Cyberlearning Tools for STEM Education.[13]

Traditionally, learning in informal environments has been studied from both the cognitive and socio-cultural perspectives[14-15], examining how people learn by interacting with different components of the informal environment such as other learners, program activities, and physical components. Several theories of learning have been advanced by researchers in the informal education field including the Contextual Model of Learning[10] and the Multiple Identities Framework[16]. One approach that focuses on the learning processes and outcomes of parents and children in these contexts is the theory of Islands of Expertise, which suggests children can "become interested and… develop relatively deep and rich knowledge" in a topic over time through small, seemingly insignificant—yet collectively transformative—conversations between parent and child (p. 333).[1] These short fragments of explanatory talk, where the parent provides information to the child on a topic of interest, are referred to as explanatoids. As the child comes to understand more about the topic from each interaction, he or she becomes more interested in the topic, ultimately leading to further conversations and deeper understanding.
These individually unremarkable interactions cumulatively provide a motivating and powerful connection between interest and understanding.[17]

The GRADIENT project explores gender differences in the development of engineering interest and expertise by examining the number, richness, and range of engineering-focused behaviors observed during parent-child conversation within three informal engineering learning environments: a pre-school program where parents and children can play with engineering-focused toys, a family-oriented engineering event for elementary students and their parents, and an engineering exhibit within a science museum.

Moreover, the study draws on prior work[18] that extended the Islands of Expertise framework beyond parent–child interactions and applied it to groups of 5th and 6th grade students working on engineering design challenges. Students in these environments carried out short explorations in the learning environment by engaging in rapid iterations of the design-build-test cycle. These iterations, or exploratoids, functioned in a manner similar to explanatoids, cumulatively forging a powerful linkage between interest and understanding of scientific ideas. The GRADIENT project also explores gender differences in the use of exploratoids during engineering activity by parent-child groups.

Finally, the GRADIENT study connects to the broader literature on girls and women in engineering by examining the extent to which girls' development of engineering interest and understanding can be impacted by connecting informal learning activities more intentionally to societal issues and problems. Drawing on the occupational choice theories posited by Eccles[4] and Lent[19], girls and women tend to place a high value on helping others in their work but do not often realize that careers in engineering can lead to these types of endeavors. Adding layers of social context that highlight the connections between engineering endeavors and improving the lives of others may create a more engaging experience for girls and women, and potentially lead to increased development of girls' engineering interest and understanding.

Research Questions

The overarching goal of the GRADIENT study is to advance the understanding of how parent-child conversations and activity within informal engineering environments can contribute to the development of girls' interest and understanding in engineering. Building on the theoretical framework outlined above, the main research questions guiding this work are:

1. What gender differences exist in the ways adult-child groups collaboratively build interest and demonstrate engineering behaviors and talk within informal learning environments? How do adult-child groups differ in levels of explanatory talk about engineering?

2. How are these gender differences affected when the learning environments are infused with connections to personal and societal issues, which have been shown in the literature to make STEM work more interesting to girls?

Study Procedures

While the GRADIENT study explores adult-daughter interactions in three different informal learning environments (a pre-school program where parents and children can play with engineering-focused toys, a family-oriented engineering event for elementary students and their

parents, and an engineering exhibit within a science museum), this paper focuses on the "Preschool Playdates" program, which is facilitated once a week at a science museum and is designed for children aged 3-6 years old. Within this context, we have set up an engineering station, where children and adults are invited to engage in engineering design-build activities with the understanding that participating in these activities also entails participation in the research study. The child(ren) and adult(s) attend to two different engineering challenges ("design a tower as tall as this plant out of foam blocks" and "design as tall a tower as you can using the Dado Squares"), working on each task until the child is ready to be done, while video-recorders capture the family's interactions (see Figure 1). The two challenges were selected to capture variation based on familiarity with the building materials; the children are typically familiar with the foam blocks, but not familiar with the Dado Squares. Once both challenges are finished, the child is interviewed using a puppet methodology[20-21] while the adult completes the short-version of the Parents Engineering Awareness Survey[22]. While most children respond favorably to the puppet during the interview (providing more explanation to the puppet than they would to an unknown adult), we have found that the puppet is distracting for some children. In these cases, the researcher asks the puppet to "take a nap" for the remainder of the interview (see Figure 2). The puppet methodology used for this study is described in greater detail in another paper.[23]

Dyad building a tower with foam blocks   Dyad building a tower with Dado Squares

Figure 1. The two design challenges adult-girl dyads engaged in.

Figure 2. Puppet interview in progress.

Preliminary Findings and Analyses

Data has been collected from 33 adult-child dyads (we focus on girls as the overall objective of the project is promoting the participation of women in engineering). Participants are selected to join based on the child's age (4-6 years old) as well as adult's sex (for equal numbers of male and female participants). Adult participants were mostly parents, but some were Aunts, Uncles and even a Grandfather. Data includes audio and video-recordings of both design challenges (foam block towers and Dado-square towers), audio and video-recordings of the interviews with the children (as well as transcripts), and the completed parent survey.

Engineering Vocabulary

The 33 transcripts for the Playdates Baseline were reviewed for terminology relating to engineering and science concepts uttered by either the adult or child participant. The frequency of the related words used during both design tasks are listed in Table 1. Three adult-child dyads did not utter any significant vocabulary (e.g. minimal discussion, simple exchanges).

To determine whether the words "counted" as engineering vocabulary, six engineers (4 who speak English as a first language, 2 who speak English as a second language) and 1 non-engineer reviewed the terms as to their applicability to engineering. Table 2 lists the words that are associated with engineering vocabulary. A "high" association was assigned if six or seven people considered the terms to be related to engineering, whereas "moderate" had three to five people and "low" had two or less. Some of the words were not associated with engineering, such as those that were more associated with science (e.g. tornado, magnets) or math (see Table 3 for a category break down).

The context in which the words were used was important in determining their relevance. For example, a young child attempted to describe a "right angle" to their parent, but instead said "right in the angle". In another dyad, a mother commented on how her daughter sought to make the tower "pretty" by using the colored blocks in a pattern and commented that they "focused on architecture instead of height".

Table 1: Frequency of engineering terminology used during a design task involving an adult and a young child across all participants (n=33).

#	Words or Phrases Used
8	Balance, Taller, Higher
7	Bridge, Wobbly
6	Base, Stable,
4	Heavy, Idea
3	Sturdy, Tip, Tippy, Weight
2	Big bottom, Cube, Foundation, Measure, Tilt, Trapezoid, Tunnel
1	Architecture, Builder, Conclusion, Design, Diagonal, Direction, Engineering, Fix, Force, Height, Horizontal, Leaning, Loose, Magnets, Module, Planned, Pressure, Right in the Angle, Right Length, Stabilize, Stabilizer, Stand on End, Standable, Stronger, Support, Teeter-Totter, Test, Tornado, Unstable, Vertical, Wider, Wiggly

Table 2. Level of association with engineering for vocabulary terms used by dyads

Low	Moderate	High
Architecture	Balance	Design
Base	Fix	Engineering
Builder	Force	Measure
Conclusion	Foundation	Stabilize
Cube	Height	Stabilizer
Diagonal	Horizontal	Stable
Direction	Idea	Sturdy
Heavy	Module	Support
Stand on End	Planned	Unstable
Tippy	Pressure	
Trapezoid	Test	
Tunnel	Tilt	
Wobbly	Tip	
	Unstable	

* All words were not assigned engineering association.

Several of the words also were similar in scope and nature, and were put into several different categories: stability, foundation, science, math and design (Table 3). Almost half of the participants used stability terminology such as balance, tip and wobbly. One mother-daughter dyad used the word "stabilizer" to indicate that a certain block would help to keep the tower from falling over. A quarter of the participants also mentioned words relating to foundation terminology, science, and math.

Table 3. Percentage of adult-child dyads using particular words during the design activity

Category	%	Example Words
Stability	48	Balance, Leaning, Stabilize, Stabilizer, Stable, Standable, Support, Teeter-Totter, Tilt, Tip, Tippy, Unstable, Wiggly, Wobbly,
Foundation	24	Base, Big Bottom, Foundation
Science	27	Tornado, Magnets, Force, Pressure, Balance
Math	21	Right Angle, Measure, Cube, Trapezoid, Height
Design	18	Design, Idea, Planned, Test, Measure

* Note that some words are in multiple categories.

In looking at the adult-gender differences in vocabulary use, males used a larger variety of engineering vocabulary than females, though total quantity of utterances were similar. However, women tended to use words that had a higher association with engineering.
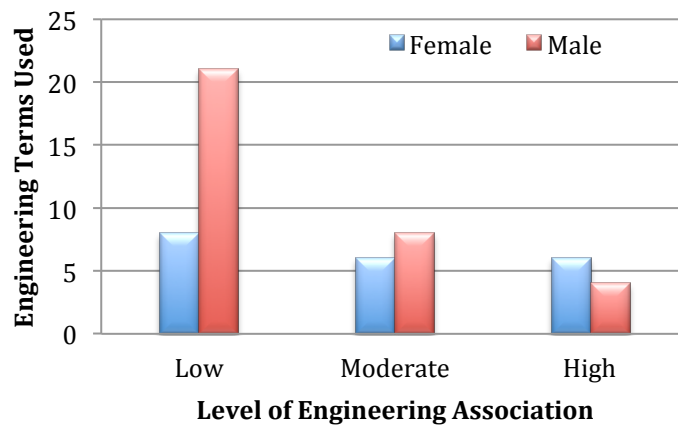
Figure 3. Differences in adult engineering vocabulary use according to sex.

Versions

A version starts when either the child starts collaborating with the adult (series of joint activities/conversation happening close together in time), purposefully places one block on the ground or puts two blocks together. A version ends under three different conditions: 1) when the child says they are done, 2) when they leave the activity space or 3) when 50% or more of the structure is removed. Children do not need to be actively touching blocks to be "building". Two researchers independently timed the versions and then compared their results until they reached a consensus.

A total of 112 big foam block tower versions (34 first versions and 76 total subsequent versions) was observed, with an average time of 2:15 for the first version, and 1:34 for the subsequent version(s). On average, a dyad undertook 3 separate versions, with a maximum of 7. For the Dado squares there was a total of 79 versions (i.e. 33 first versions, as one group did not finish both tasks, and 44 total subsequent versions) with an average time of 2:36 for the first version and 2:31 for subsequent versions. The number of versions per dyad ranged from 1 to 14 with an average of 2 versions. (Note: An additional case was analyzed that was not included in the vocabulary analysis).

One early finding is that once families get past an initial iteration (i.e. a version of the tower), subsequent iterations tend to be shorter. This may suggest that families spend less time thinking through design decisions after the first iteration, which may function as a more exploratory iteration. In addition, adults tended to initiate iterations more frequently than children during the Foam Blocks activity, while initiating equally during Dado Squares activity, suggesting that perhaps the activity structure or materials may play a specific role during family learning about engineering.

Focused Analysis for Seven Cases

Additional analysis has been conducted of the video recordings for 7 of the 34 dyads. For these 7 dyads, video recordings for each family were segmented by iteration and analyzed for parental role, length of time, and the introduction of additional context to the activity by parent or child.

To examine parent roles, we built on Beaumont's (2010) Adult Child Interaction Inventory[24] to look at instances of parents adopting roles of facilitator, interpreter or player.

Based on our early analysis of 7 dyads, there are two preliminary findings that are particularly interesting: 1) parent roles tend to shift throughout the observation, and include facilitating, playing, and interpreting, (with "facilitation" being the role that is most commonly adopted, followed by "play" and "interpretation") (in order of frequency, see Figure 3 below) and 2) both parents and children add context to the building activities, providing a narrative element to the experience (see Figure 4). We found that adults tended to add context more often than children, and six out of seven families added context while building. These layers of context ranged from identifying a type of structure being built ("I think this is a chicken coop!") to an elaborate story about building a tower for particular castle.
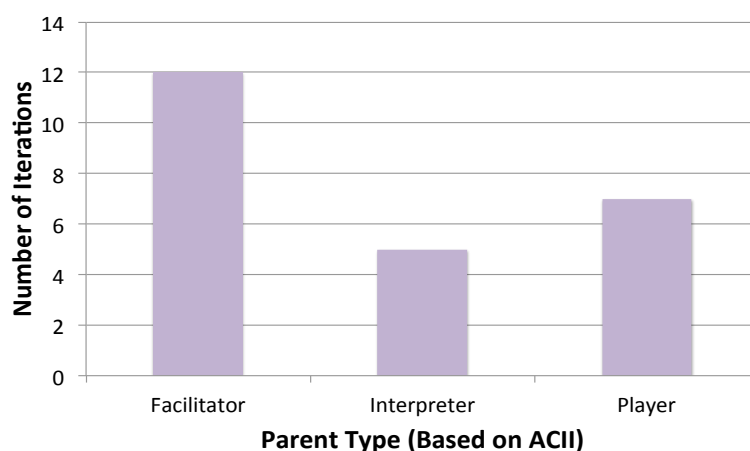

Figure 4. Roles assumed by parents during building activities.
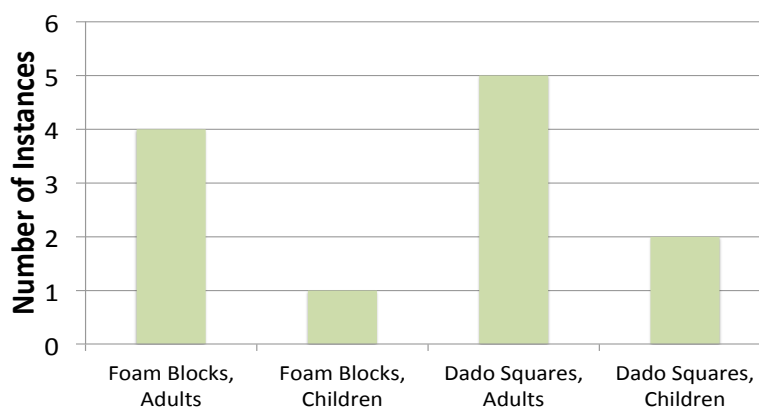

Figure 5. Number of instances of addition of context to building activities by parents and children.

As the analysis continues, we are continuing efforts to segment and code the data. Each of the video recordings is transcribed and segmented based on idea unit, consistent with the Verbal Analysis approach described by Chi (1997).[25] Initially transcripts are segmented by multiple

coders to establish consistency in how the segmenting is conducted. Once all video recordings are segmented, each transcript will be coded according to three different coding schemes: (1) engineering behavior (2) parent-child interaction, and (3) interest. The current form of the coding schemes is presented in Table 5. Once coding is complete, we will be able to examine the data for patterns in terms of relationships between parent-child interactions and engineering behavior; frequency of parent-child interaction type; frequency of different engineering behaviors; and differences based on parent sex and parent educational background (especially the parent's engineering and science background).

Table 5: Current Version of the Coding Scheme

Theme	Code	Sub-code(s)
1. Elements of Engineering Behavior	A. Problem Scoping	Constraints, Context, Material Use (Exploration, Feedback, Requirement, Evaluation), stakeholder
	B. Planning	Brainstorming
	C. Modeling	Iteration/revision,
	D. Evaluation	Optimization (tradeoffs, prioritization, efficiency), Negative feedback
2. Adult-child Interactions	A. Directing	
	B. Asking questions	
	C. Prompting reflection-on-action	
	D. Following lead	
	E. Providing affirmation/encouragement	
	F. Having conflict/disagreement	
	G. Explanation	Reference real-world examples, connect to child's daily expertise, explanatory statement
	H. Other	Distracted conversation, conversation directed at another.
3. Interest	A. Enjoyment/excitement	
	B. Frustration	

To test the validity of the coding schemes, we shared our preliminary work, two video recordings, and our current coding schemes with three expert advisors: an expert in developing and implementing informal engineering programs; an expert in research on early childhood learning experiences as well as research on learning in informal settings; and an expert on gender studies. One early piece of feedback from one of our expert reviewers was to focus the engineering behavior coding scheme around key engineering behaviors, rather than exploring all possible engineering behaviors. While the data we have collected provides rich insights into early engineering behaviors and engineering thinking, a more focused analysis allows for stronger initial findings, where we investigate how (and when) children engage in specific engineering behaviors, and how the children's ways of engaging in specific engineering

behaviors may differ from the ways that adults engage in the same behaviors. Hence we narrowed our focus to the behaviors presented in Table 1: problem scoping, planning, modeling, and evaluation. These three behaviors were chosen based on (a) the literature on expert-novice differences in engineering design and (b) observations based on our video data.

Research suggests that experts tend to spend more time engaged in problem scoping activities compared to novices, and that this additional time spent scoping the problem leads to higher-quality engineering design solutions.[26] Additionally, as previously noted, we found that both the girls and the parents in our study added context to the tasks that we asked them to complete. This "context adding" is one dimension of problem scoping. Research also suggests that experts tend to engage in more iteration that novices – both in terms of cognitive iterations (movements between different design activities—that is, spending time defining the problem, then working out details of the solution, then going back to reconsider how the problem is defined) and in terms of number of versions of the solution. [26,27] In our video data, we also see variation in the number of different versions of the towers different families completed, as well as "movement" between different design activities (e.g. problem definition and solution detailing). Finally, the recent NAE report on K-12 Engineering[28] suggests that iteration is a key aspect of engineering that differentiates engineering from science. Preliminary analysis of our video data shows that children engage in optimization strategies as part of their design-build processes, such as trying to minimize the amount of space between the different shapes (trying to fit shapes together like a puzzle while building the tower with foam blocks) or in other cases trying to maximize the amount of space between shapes (to make use of negative space to create a taller tower).

Conclusions and Contribution

Previous research has suggested that different parents will adopt different types of roles while interacting with children in engineering activities. With this study, however, we see individual parents adopting different roles at different points in time. Since parents can and do adopt a variety of roles while interacting with their daughters, we wonder: does the percent of time spent in each role differ based on parents' background (do engineer parents spend more time interpreting the activity than non-engineer parents?)? And how do the different roles impact the girls' experiences with the engineering activity?

The tendency for both parents and children to add context resonates with research that suggests that girls are more interested in pursuing activities and fields of study that are socially relevant— that is, by demonstrating the social relevance of engineering, and the larger context of engineering problems, we can attract more women to engineering. This finding is promising, and this suggests that parents may already be helping their daughters to connect engineering–related activities to a larger context, thus increasing their daughters' interest in these types of activities.

Through this work, we hope to significantly impact the ways in which girls are able to begin cultivating a lifelong interest in engineering at a young age, which may ultimately encourage more women to pursue engineering careers in the future, through focusing on the types of interactions that girls have with their parents. By examining current family patterns, we hope to identify recommendations we can make to other parents on how to foster engineering interest in their children, as well as contribute ideas for activities for K-5 classrooms to reach a wider range of children.

Acknowledgement

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