Knowledge Transmission and Engineering Teaching

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Abstract: This paper explores the concept of knowledge as well as the process of knowledge transmission, both in general and specifically regarding engineering knowledge. This study focuses on twenty-four parents who discussed the activities that they engage in to help their children learn about engineering during hour-long interviews. The intergenerational transmission of knowledge that is described in the interviews is analyzed through 1) social structural and cultural analysis, and 2) a case study. We find that parents teach children what they perceived as engineering knowledge, which is not necessarily true but rather subjective, and believed to be a fact based on the parent's other forms of knowledge learned in the past. Understanding this will help us look at engineering education from a new perspective, and the application of this understanding could be used to help provide non-engineering parents alternative ways to support their wish to explore engineering knowledge with their children.

Introduction

This paper deals with pre-college students' engineering education within the backdrop of the current state of pre-college engineering education in the United States: while engineering has traditionally not be explicitly taught in the K-12 schools as a subject, there is growing interest in incorporating engineering in K-12 schools (e.g. NAE and NRC 2009). A small number of states have even begun adopting engineering curriculum standards. However, as this is a recent change to K-12 education, there is little research on engineering pedagogical content knowledge or the impact of engineering instruction on students' understanding of engineering. As such, rather than focus on expert teaching practices exhibited by K-12 teachers, this study focuses on the teaching practices of engineering parents. While this expertise may not always translate to practices that classroom teachers can adopt, we believe that some of the parents' practices can inform classroom instruction as well as the development of resources for non-engineer parents. Additional motivation for the study is based in a desire to increase diversity in engineering at the college-level and beyond (i.e. post baccalaureate studies and industry practice).

In order to investigate the practices that parents with engineering backgrounds employ to help their children learn about engineering, we interviewed 24 parents who self-identified as parents of children aged 2-18 who "help their children learn about engineering." As we selected our study participants, we were careful to include parents from different engineering backgrounds in addition to academic vs. industry vs. mix-of-industry-and-academic backgrounds, as well as parents of children of difference ages and sexes. Each parent participated in a semi-structured interview that last approximately 60 minutes. We began by asking about their children; their children's schools; their academic background. Then we asked them about how they helped their children to learn about engineering, and asked follow-up questions based on their responses.

The interviews were conducted among 24 participants, among whom there are 12 males, and 12 females. 14 parents out of 24 are faculty members, 2 are PhD students, and 8 are in industry. Both of the parents who are PhD students have had respectively 9 to 30 years working experience in industry prior to the PhD program. The parents' work and educational backgrounds touch on 20 specific engineering fields, such as civil engineering, biomedical engineering, aerospace, electrical engineering, and industrial engineering. Out of their 50 children, 26 are girls and 24 are boys. Their ages range from 17 months to 29 years old. Besides 11 outliers, there are 39 children who age from 2 to 18. The interview questions have covered parents' background, interactions with children (content they teach their children, teaching strategies, and children's reactions), parenting ideology, and parents' own understandings of engineering.

In this paper, we use these interviews to explore parents' roles as teachers; how knowledge is transmitted intergenerationally; and interplays of socio-cultural factors and parents' own history of learning that impacted parents' activities. We do this by focusing on four participants: Laura, an Asian mother of one son and one daughter and is pursuing a PhD in software engineering; Liz, a Professor teaching biomedical engineering who has a four year old son; Tom, a father working in the industry with an engineering background covering several fields (metallurgical engineering, material engineering, and process engineering) and who has a 2.5-year-old daughter and a 5.5-year-old son; and Aaron who is a father of a 4.5-year-old son and is a professor with an electrical engineering background.

We begin this paper by discussing the concept of knowledge. By dividing knowledge into specific knowledge and common sense knowledge, we are able to analyze interplays of the two during the process of the intergenerational knowledge transmission– how the former is based on and restrained by the latter which is deeply embedded in and in turn reinforces the former. The process of intergenerational knowledge transmission is analyzed on two levels – social structural and cultural analysis and processual analysis. In order to understand the meaning of parents' teaching activities, we have to look at the social structure and cultural environments in which these practices are performed. Structural analysis as a methodology thus helps us understand 1) that parents' educational practices are shaped by the basic principles of their common sense knowledge, 2) their ideology of education functions as to ensure the common sense knowledge to be put in their daily practices and obeyed, 3) how different social systems such as families, engineers, and different ethnic groups are integrated, 4) how individual parents justify their practices through scrutiny, and 5) how through the interaction between individual parents and the society, both the parents' goals and the social expectations become realized.

Knowledge transmission through teaching and learning

In a footnote of Foucult's Archaeology of Knowledge (Foucult, 2002:16), his translator A. M. Sheridan Smith wrote:

> "The English word 'knowledge' translates the French 'connaissance' and 'savoir'. 'Connaissance' refers to a particular corpus of knowledge, a particular discipline – biology or economics, for example. 'savoir' which is usually defined as knowledge in general, the totality of connaissance is used by Foucult in an underlying, rather than an overall, way. He has himself offered the following comment on his usage of the terms:
>
> > 'By connaissance I mean the relation of the subject to the object and the formal rules that govern it. Savior refers to the conditions that are necessary in a particular period for this or that type of object to be given to connaissance and for this and that enunciation to be formulated'
>
> Throughout this translation I have used the English word, flowed, where the meaning required it, the the appropriate French word in parentheses."

There are two types of knowledge implied in the above message which are not mutually exclusive. One is expertise or skills gained in a specific field through education or learning; the other is implied above by Foucult, that is – different epistemologies we believe in and practice every day to know and make sense of the world (i.e, common sense knowledge). However scientific the former might be, it is always limited by the latter which we practice almost unconsciously in everyday life. However encompassing our common sense knowledge might seem to be, our specific knowledge gained from systematic learning in turn reconstructs our common sense knowledge by a series of rejections, confirmations, and readjustments. Therefore, as Hansen states, "the transmission of knowledge is subject both to conservative forces and to tendencies toward continual redefinition" (Hansen, 1982:26).

In our case, the specific knowledge being transmitted from parents to children is more transparent. The knowledge is everything that parents think is engineering related – fixing a household item, building an electric circuit, practicing mathematics skills, understanding how things work, etc. The common sense knowledge, however, is more complicated, pervasive, and taken for granted during most of our waking hours.

According to Hansen (1982), common sense knowledge – which he calls cultural knowledge – is a set of maxim, ideas about human nature, aesthetic preferences, values, affective patterns, beliefs, etc. (Hansen, 1982:25). According to Leiter (1980) and Schutz, common sense knowledge does not only include the "rules of thumbs that are vague, contradictory, and self serving", but it can be studied from three dimensions – the stock of knowledge, the natural attitude of everyday life, and the practices of common sense reasoning (Leiter, 1980). Much of these dimensions hinges upon the various assumptions people make about each other and each other's reasoning. In this study of parents' teaching experiences, we examine the process of knowledge transmission by looking at the interactions of these two types of knowledge and how parents reorganize these types of contradictory as well as mutually sustaining knowledge to selectively teach it to the next generation.

Structural & Cultural Analysis

Knowledge transmission reflects social structure. Social structure is viewed by Sewell (1992) as "dual", as "both the medium and the outcome of the practices which constitute social systems". Social structure also "differs in 'depth' (how pervasive, invisible, and taken-for-granted their schemas are), and 'power' (how great the resources they generate from)" (Sewell, 1992:22-6). Practices are therefore enabled as well as constrained by social structure, and these practices in turn make the transformation as well as the continuity of social structure possible. Parents' everyday teaching practices such as the types of knowledge selected by parents, their children's expected responsibilities and privileges, and the descriptions of children's "good" and "dissatisfying" performances (which reflects their core values) are enabled and constrained by what facilities are around the parents, what methods are favored by the mainstream culture (e.g., what they see from the mass media), what parents can afford to do, what parents' peer groups are doing, and how parents cope with their children's school curriculum.

In our 24 interviews, there are two channels through which parents teach their children engineering related knowledge: material resources and daily interactions. These two channels are not necessarily mutually exclusive. The most commonly used material resources are manipulative toys, computer programs, websites, books (either literature or science oriented), TV programs and DVDs, and trips to museums or exhibitions. The use of these resources is largely determined by the manufacturing and consumption preferences of the society, distribution of knowledge and skills, relationship between specific knowledge and its financial reward as well as its social reward, access to the resources due to the parents' social class, parents' financial ability, household locality, and the children's age, gender, birth order, and their assumed personality.

For example, the parents' financial ability decides what types of toys are on the top of their hierarchy and for what purpose the parents are buying the toys. Laura (1), one of our parents who participated in the study, mentioned that she used Barbie dolls as tools to help her daughter practice counting when she was 2 years old. In contrast, imagine a low-income family with many children. Here, the parents might use objects that are more practical and affordable or objects that they already have in their possession. The purpose of buying a Barbie doll is different, too. For a low-income family, parents may buy their children a Barbie doll based on their wish to provide their children a toy that other children possess. In contrast, Laura might have multiple different considerations. For example, a different Barbie doll would increase the variety of toys for her children, and the toy itself can be used as a teaching mechanism (and Barbie's latest career as software engineer, though announced after our study concluded, may provide yet another opportunity for parents to teach their children engineering concepts) .

Another channel through which parents teach their children engineering concepts is daily interactions. Some parents take 10 to 20 minutes every night to answer some questions before their child goes to bed, usually curious questions about nature. In doing so, they claim to encourage their children's curiosity, a characteristic which is highly valued in a middle class American family with both parents systematically and well educated. Some parents invented a mini project such as building an electric circuit or fixing an old computer to engage their children in the problem solving process in a "natural" environment. Most parents have taken their children to work, and some of them have exposed their children to specific objects they use at work. According to the Neo-Marxist conflict theory (Collins, 1985), such a way to organize interactions reflects the social status group of the parents. Additionally, through associations with members in the same group, the parents share common status cultures such as language styles, parenting styles, requirements for education, interpersonal dynamics, values, topics, etc (Collins, 1985). Such ways in which educational interactions take place make it possible for the children to become technologically capable, curious, creative, and able to fix problems. These are expectations that overlap in both the macro American culture and the engineering culture specifically and are constructed under these certain social structures. In meeting the expectations, the social structure in turn is reinforced.

The above analysis is not to imply that these parents – who share a similar social class status, academic backgrounds, parenting styles, and expectations for children – as a group are homogenous. The knowledge these parents choose to pass on to their children through selected strategies reflect the integrated core values of 1) the mainstream Anglo-American culture, 2) the microscopic engineering culture, 3) various subcultures (race, gender, nationality, etc.), and 4) the parents' historical experiences. For example, students in American culture are encouraged to take initiative and be motivated to learn. "Students are expected actively ask questions and participate in class discussions and other activities; they are frequently rewarded for contributing to the class and giving critical and constructive ideas" (Pai & Adler, 2001:221). Self-motivation, independence, curiosity, and creativeness are considered as desirable qualities (Pai & Adler, 2001). Children are expected to reflect such qualities as well. Liz, who is a professor teaching biomedical engineering, complained that her son doesn't have initiative to learn. When we asked her to describe her son, she carefully said that her son is "different" from other kids in the sense that he doesn't seem to have a lot curiosity, and he doesn't ask a lot questions. Liz's worry came from the awareness that her son doesn't have some of those core values that are preferred by this society: curiosity and initiative. While every other kid is praised for being curious, Liz is concerned that her sons' passive learning characteristic will not help him succeed.

As Swidler (2001) postulated, social structure depends on the mutual reproduction of schemas and resources. Schemas are the semiotic codes shared by a group of people and used by them to make sense of the world. A schema is what makes a resource meaningful as a resource (2001: 78). Take our parent study as an example. These parents with engineering backgrounds are well educated by formal institutions with at least a Masters degree while some have a Ph.D. The engineering schemas – such as solving an engineering problem –

that are deeply embedded in heavily scripted engineering classroom interactions are internalized. Thus when parents who share the same engineering schemas see a child taking a toy apart, they think of the action as initiating a problem which leads to the next step – putting the toy back together. However, parents who don't share the same schemas are more likely to blame their children for breaking the toy and possibly causing unnecessary financial repercussion. The schemas parents internalized during their own learning process became their own rationale they use to interpret resources and interact with their children who in turn learn to interpret things by using the same schemas. With the ongoing mutual reproduction of resources and schemas the social structure is sustained.

Different parenting styles may also be attributed to different sub-cultural backgrounds. Aaron, who is a professor described how he took his son down to their basement and explained to him the structure and functions of the water pipes. Laura, who is a Chinese woman pursuing her Ph.D. in America says that she is not very satisfied with the mathematics education here. "There's too much play-work here in American elementary schools", she said, "I still think the Chinese way is better". She gave her children math practices to do and graded them like a teacher. Our interviews suggest that parents within engineering fields but with different specializations have different understandings of what engineering is and therefore have different focuses on teaching what they think is engineering related. Parents who see engineering as problem solving are more inclined to initiate a small project to get their children involved, and the focus is on how things work. One parent who calls herself a "soft engineer" (which is generally associated with problem solving, design, communication skills, and teamwork) focuses more on the basic scientific and numeral skills which she thinks are fundamental and crucial to engineering. Tom, who has worked in industry for a long period of time (as opposed to other parents who are in academia) sees that engineering is not always problem solving but most of the times is just maintaining, to "keep the machine running" as he said. However, his teaching strategies don't seem to be too different.

According to Durkheim's social order theory, the study of social structure focuses on the moral order, the central value system that though created by people, has an independent and external existence and acts as a constraining and conditioning force upon individual people (Meighan and Sirah-Blatchford's, 2003: 252). Parsons, like Durkheim, saw social order achieved through the operation of an integrating system common to all members of society; yet he also emphasizes how individuals constantly adjust themselves through scrutinizing the process of socialization (2003:256). Structural analysis as a methodology thus helps us understand 1) that parents' educational practices are shaped by the basic principles of their common sense knowledge, 2) their ideology of education functions as to ensure the common sense knowledge to be put in their daily practices and obeyed, 3) how different social systems such as families, engineers, and different ethnic groups are integrated, 4) how individual parents justify their practices through scrutiny, and 5) how through the interaction between individual parents and the society, both the parents' goals and the social expectations become realized. Further, the integration of structural analysis, cultural analysis, and Swindler's understanding of structure as the mutual reproduction of schemas and resources provides us a different perspective that gives meaning to parents' teaching activities. Therefore, we not only focus on the relationship between individuals and society, but also the meaning of individual practices under certain schemas constructed by the members of the society (e.g. a child taking a toy apart is perceived by engineering parents as an aspect of curiosity and an initiative step to problem fixing). However, the study of social structure and culture focuses on the relatively stable features of behavior and context and the patterned arrangement of relationships among individuals and groups while leaving the problem of process untouched. We are also interested in the process of how these schemas came into being and how parents reorganize the messy and conflicting knowledge from different levels of social systems and transmit the knowledge to the next generation. In the following case study, we delve into these processes by analyzing a specific interview with a female engineer who we think is particular in representing both conflicts and integration of all kinds of knowledge she is trying to pass to her children.

Case Study

Our case study will center on an interview with a female engineer and parent. In order to better reveal the process of intergenerational knowledge transmission, in which the parent tried to put different pieces of knowledge (engineering knowledge, the parent's own cultural background, and the mainstream American culture perceived to be true by her) together, we follow Hansen's suggestion (Hansen, 1982, 1990) by dividing the following analysis into several steps. These steps will allow us to see how the social structures are created, maintained, challenged, and modified over time as well as process an individual's adaptation necessary to his/her changing environment (Hansen, 1990: 192). The steps are: 1) the definition of the situation; 2) the cultural significance associated with communication channels used to encode and decode communications; 3) the interplay among channels of transmission; 4) the communicative-interpretive repertoires of participants, including communicative competence in the codes being used, 5) the communicative strategies participants used to realize their respective interests and purpose, and 6) the role and identity attributions.

Laura is a Chinese woman pursuing her Ph.D. degree in engineering, specialized in software programming, computer networks, and information security. Her husband is also an engineer and currently working in industry. Prior to pursuing her Ph.D., Laura had eight years of industry experience. Laura has two children, a son and a daughter. In the following conversation, you will see Laura trying to tell the interviewer what kind of engineering related knowledge she taught her children. She also stated that she was a "soft engineer" and that many things she had to do at work are math related. Therefore, she viewed math as fundamental for engineering.

> Interviewer: so you started doing that after they have learned some math at school?
>
> Laura: yes . but actually , their math, uh-mostly, I uh taught them math because their math is more advanced than what they are learning at school?[Interviewer: uh-hmm] so I uh, the-they learned their math at home, basically. ((chuckle))
>
> Interviewer: Oh, OK. So-
>
> Laura: [Schools, especially middle schools here are not too demanding here in America? I would say American education here, eh- even in the best middle schools, in west Lafayette, I know a lot of parents, the way they teach math, I think it's not demanding enough, so that if I don't teach them at home, I feel like their talent will get wasted. So ((chuckle)), that's how I feel.
>
> Interviewer: So are there other ways in which you tried to explain math to them?
>
> Laura: um, see, uh-here in America, we like to say let's play games and do math. [Interviewer: uh-hmm]And we don't do it that way. I do it in the Chinese way. I came from china, and I, and I-learned my way there. Ah-I teach them Chinese way((laugh))
>
> Interviewer: [OK. So it's kinda like complementary-
>
> Laura: [yeah I thought it was very important. ((laugh)) [A: OK. That's interesting.] I actually think the Chinese way of teaching math is better? ((laugh))

According to her description, her definition of the current situation was that she is not satisfied with both the depth of the math education in America in general and the play-work teaching strategies she has observed from other parents and schools. The school was wasting her children's talent. She expected that teaching her children math the Chinese way would stop her children from falling behind where they were supposed to be, were they raised in China.

Apparently there are two conflicting communicative channels that are associated with two different cultures. One channel is associated with mainstream American culture and stresses the importance of autonomous study, independence, initiative, and having fun, especially at the level of elementary school. The other channel through which the knowledge is transmitted is associated with Chinese culture which values cooperative study, passiveness (e.g. students are expected to follow the guidance and authority, and learn through watching, listening and emulating), memorizing the knowledge, and heavy practices. In general, American school personnel see schooling as a process of developing the whole person (Pai &Adler, 2001:220-223). Thus non-academic activities are considered an important part of schooling. Playing, for example, is perceived as a strategy to initiate children's curiosity to learn as well as a way to develop the children's social skills. As Spindler and Spindler (1990:37) generalized, one of the core values of the Anglo-American society is a sociable, get-along-well orientation. The ideology of early children's education is also to explore and support their own interests instead of pushing them to any one direction (which is almost a taboo in the interviews with parents). However, in a Chinese mom's eyes, playing at school – where only academic related activities are supposed to take place – can be a distraction to the child's intellectual training and cause anxiety for the mother. Being a Chinese mom, Laura also expects her children to be among the top students in their classes. Even though she claimed that she didn't intend to push her children, she was very proud when she told me that her son had won several math competitions and her daughter – who didn't show very much enthusiasm in math – was a year ahead of her classmates. Facing this anxiety, Laura felt the impulse to change the situation. She then went on to tell me how she achieved this change.

Another channel through which Laura teaches her children engineering related knowledge is associated with the history of her engineering learning process. Most of Laura's education was done in China where she also had 8 years of experience working in engineering industrial practice. She is also currently studying for her Ph.D. in engineering in an American institution from which she has internalized the core engineering values in the U.S. through her learning practices. Her perspective of what engineering is can be very different from the mainstream perspectives as we shall see below:

> :: (My daughter)-she's very self sufficient,? She, she, she cooks her own pancakes,?((chuckle)) [A:oh] so we think that would related to engineering. you wouldn't think cooking and engineering (*are related*), but engineering, uh, you follow a direction, mix the eggs and flour together, ((laugh))[A: right]. I think that'll will be good-]
>
> Interviewer:
> [It's a, i-it's a process of production?
>
> Laura: Right. Production. And also you know the modern grinder, the mixer. So 'cause grandma has to do it by hands, she does it by hand. And with the mixer, they know this is the-because there is engineer.(ing).

The above conversation shows that engineering is perceived by Laura as a symbol with two meanings: 1) engineering is to "follow a direction" or follow instructions, and 2) engineering is to design innovations which improve our lives. The second meaning is a commonly shared meaning within the American engineering culture, whereas the first one is gained from Laura's history of learning and working in China. While the second meaning is articulated frequently and almost throughout the entire interview, it is the first meaning of engineering – follow the instruction that Laura uses to construct her real parenting practices. For example, feeling the anxiety that the school is not demanding enough at math teaching, Laura brought home many math practice sheets for her children to work on, and "I grade them like a teacher", she said. If the children did the problems wrong, she would circle the wrong answers and ask them to redo the questions. Laura also bought her children the Stanford EPGY (Educational Program for Gifted Youth), a computer based program for math, and asked them to practice by following the program's instructions at least half an hour each day. Both solutions consist of two types of instruction following: one is to follow Laura's own instruction to finish the work she gave to her children, the other one is to study math by following the instruction of the program.

When asked about what she usually taught to her children, just like all of the other parents we have interviewed, Laura felt the necessity to immediately claim that she didn't really teach her children anything specific because she wanted her children to be free to choose what they like to do. However, in the later description of how her daughter learned math, she first showed some dissatisfaction since her daughter wasn't as motivated to learn math as her son; she then said she felt lucky because her daughter doesn't really hate math even though she didn't show much enthusiasm; at last, she was proud to say that her daughter, although not as successful as her son, was still doing very good at math and her level was one year more advanced than her peers. Therefore, by articulating what is expected by mainstream society and then actually practicing under completely opposite schemas, the social values are sustained and Laura's personal purpose is realized. Laura also did not have to be fully conscious during the process of readjustment.

As we have shown above, the interview with Laura was full of contradictories. As a self-selected participant, she was attracted by our flyer looking for parents who transmit engineering knowledge to their next generation and told us that this project was interesting. She might have been interested in our project for two possible reasons: 1) our requirement of participants confirmed her self-presentation with multiple identities – a mom, an engineer, and a responsible mom (for she gives "good" education to her children), and 2) she hopes our research will provide more learning opportunities. Either reason implies her will to expose her children to engineering knowledge. However, she came to us and claimed that she had never intentionally taught her children anything specifically about engineering like almost every other participant does. She tried very hard to leave us an impression that she is a good mom, and therefore will give her children enough freedom to explore what their interests are and be supportive. However, this concept of a good mom is challenged when she saw her children doing activities that are non-academic and thought such activities might hinder her children's potential to become successful, for being a good mom also means having successful children. It is possible that she did not teach her children engineering knowledge specifically as she stated, yet the fact that she was attracted to our research was a self-presentation as an engineer who is self reflexive and aware of the many benefits our society has credited to the engineering field.

As shown above, when unfolding the process of knowledge transmission it is important to understand the definition of the situation (what is happening, who is present, and what is expected to happen next), the interactions among different channels through which the knowledge is transmitted, how individuals either consciously or sub-consciously manipulate the meanings associated with different social groups, and the process of role making within such situations. It is in people's interactions that we find things meaningful.

Summary

In our 24 interviews, parents discussed teaching their children engineering related knowledge: through two primary channels: material resources and daily interactions. The most commonly used material resources are manipulative toys, computer programs, websites, books (either literature or science oriented), TV programs and DVDs, and trips to museums or exhibitions. The use of these resources is largely determined by the manufacturing and consumption preferences of the society, distribution of knowledge and skills, relationship between specific knowledge and its financial reward as well as its social reward, access to the resources due to the parents' social class, parents' financial ability, household locality, and the children's age, gender, birth order, and their assumed personality. The daily interactions through which parents claimed to teach their children engineering knowledge have revealed different forms of knowledge that have been transmitted along with engineering knowledge. During the analysis of the process of knowledge transmission, we were able to see both conflicts and integrations of different forms of knowledge, and how parents tried to put the pieces together in order to achieve their goals of education. Both channels showed that knowledge is messy and exists in many different forms, and that when engineering is taught by parents to their children as one type of knowledge, other forms of knowledge are also inevitably active in this process. These forms of knowledge (culture, specific knowledge, schema, practice, and etc) help in shaping and in turn reinforcing each other.

Understanding the concept of knowledge and the process of knowledge transmission allows us to come out of our own bubble and look at engineering education from a different perspective. During the learning process in general, we draw the information from our stock of knowledge, assume the existence of order and pattern, and seek to organize our perceptions in such way to discern it (Hansen, 1990:4). We categorize the information by using our internalized hypotheses learned from the past and orient our ways to export the knowledge by reference to these hypotheses. During the engineering education process within the household in particular, parents teach children what they perceived as engineering knowledge, which is not necessarily true but rather subjective, and believed to be a fact based on the parent's other forms of knowledge learned in the past. In the future study, we intend to apply our understanding of knowledge transmission to k-12, and pre-school engineering education. We intend to build on the study presented in this paper through further interviews with parents as well as observations of parents and children at play. We also plan to extend the work by providing resources for non-engineer parents to use as well as using our research findings to develop activities to use in formal (i.e. classroom) settings. The study described in this paper also shows us that increasing access to engineering education for children who might not traditionally be exposed to engineering is not as simple as providing ideas for activities that parents or teachers can engage in with children; instead the parents' and teachers' prior engineering experiences and cultural experiences can deeply impact the way that they approach engineering education. Thus these engineering and cultural beliefs must be understood in order to impact pre-college engineering education.

Endnote

(1) All names have been replaced with pseudonyms.

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