



## **Informal Pathways to Engineering: Middle-School-Aged Homeschool Students' Experiences with Engineering (Fundamental)**

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# Informal Pathways to Engineering: Middle-School-Aged Homeschool Students' Experiences with Engineering (Fundamental)

## Abstract

As efforts continue to promote increased engineering learning in school settings, it is important to also consider engineering learning in out-of-school settings, including learning that takes place as part of an informal learning experience or a homeschool experience. In this paper, we explore the experiences of middle-school-aged homeschool students whose families work to promote their children's STEM learning experiences, investing time and effort to ultimately cultivate rich and diverse engineering learning experiences for their children. The findings presented in this paper are based on interviews and surveys of 10 middle-school-aged children and their parents who participated in a longitudinal study of informal engineering learning. These findings provide insights into how homeschool parents access engineering learning resources, as well as the breadth of opportunities available for engineering learning in out-of-school settings.

## Introduction

Engineering as a K-12 subject has received increasing attention over the past 15 years, beginning with its adoption in Massachusetts state standards in 2001, its presence in 41 states' standards by 2011 [1], and finally the inclusion of engineering in the Next Generation Science Standards that were released in 2014 [2]. Engineering has also been a focus for numerous out-of-school initiatives, including Girl Scouts, 4-H, Boy Scouts, afterschool programs, media project like Design Squad, National Engineers Week, and FIRST Robotics Competitions. These efforts – to include engineering in formal education settings as well as informal settings – have been motivated by three major factors: (1) a push for equity and access, where there is parity in the participation of men and women, people of all ethnic backgrounds, people of all socio-economic backgrounds, and people of different abilities; (2) a concern for a workforce shortage; and (3) a focus on global competitiveness, where engineering education can promote both the learning of math and science and an engineering-literate society, which has the problem solving and technical skills needed to be globally competent.

In light of the first and third motivations for pre-college engineering education, we must consider the experiences of *all* pre-college students as we work to characterize their involvement in engineering learning. While an increasing number of research studies have examined the experiences of students across the K-12 continuum, from a range of geographic locations and socio-economic backgrounds, one group of students that has been largely overlooked by engineering education researchers is homeschool students. As of spring 2011, approximately 1.77 million students in the United States are being homeschooled [3, 4] and the homeschool population is growing at a rate of 2-8% per year [5]. There has been research examining the impact of teacher professional development on traditionally schooled students engineering learning [6], but none on the processes by which *homeschool* parents learn to support their children in their engineering studies. There have also been studies researching student engineering learning in school settings, as well as student engineering learning in out-of-school settings – but not the engineering learning of students who experience in- and out-of-school as fluid and blurred.

Understanding the experiences of homeschool children and their families can have far-reaching implications for traditional school settings. Homeschool settings have the potential to be exemplar cases of truly student-centered learning experiences. For instance, where parents follow an un-schooling approach [7, 8] the homeschool students and parents are able to allow the students' interests to guide the learning activities. Understanding how a child's interest in engineering develops in these cases, where engineering can become the central focus of learning, and barriers of fixed school days, fixed school calendars, and testing are removed, can provide insights into how engineering learning progresses. How different activities support the development of an interest in and understanding of engineering can help other parents and teachers consider how they might foster these in their own children and students.

This paper examines the engineering learning experiences of 10 homeschool families. These 10 families represent a subset of a larger study aimed at investigating how informal engineering programs support engineering-related learning over time. In this paper, we address the questions of:

*How do informal engineering programs for middle-school aged homeschool populations support engineering-related learning over time?*

*What are the ways in which homeschool families experience engineering education, particularly through informal engineering programs?*

For this study, we are defining “*informal engineering programs*” as activities, resources, and events that occur outside of a school setting, which children can engage in alone or with others, on their own time outside of school. Such programs may be self-regulated, assisted by a parent, or led by an informal educator (e.g., a camp counselor).

### **The Informal Pathways to Engineering Study**

To answer our research questions, we created a longitudinal study following 60 middle school students in two states. 10 of these students are not traditionally schooled. 8 students are currently homeschooled by their parent(s) and 2 students attend virtual public schools and have instructors who are not their parents. (We defined homeschool students as students who do not attend a school on a daily basis outside of the home.) We are in the process of collecting data via surveys and interviews annually from students as they progress from sixth to eighth grade. Students, parents, and educators (informal and formal) are being interviewed at three different points in time. The data presented in this paper is based on the first two interviews, with the third round of data collection scheduled for later this spring. In addition to participating in the interviews, students and parents are also asked to complete surveys at each interview milestone, and periodically throughout the study. This paper focuses only on the homeschool student population; interim findings from the larger study can be found in other papers (e.g. [9]). With the surveys and interviews, rather than using the term “engineering,” we discussed the children's interests and engagement in “creating, designing, and building.” (See Appendix A-1 and A-2 for the full first-year interview protocols.) This terminology was chosen in order to capture the experiences of children who might not immediately recognize how their interests were engineering-related or self-identify with the term “engineering.”

## Preliminary Findings

As noted above, data collection and analysis for this study is ongoing. From the first two years of data collection, we are finding that families choose to homeschool their children for a variety of reasons, including the fact that they recognize their children are self-motivated and independent learners, and that they want to support their children in pursuing their own interests. The homeschool parents in our study tap into a wide array of informal engineering education resources, including magazine subscriptions, websites, clubs, curricula, and tutors. However, as their children get older, it appears that the homeschool parents are getting more anxious about being able to prepare their children for college, including their ability to access resources that foster their children's growth and interest in STEM, especially engineering. They also appear to lack confidence that they themselves will be able to teach STEM to their children. This has led a few families in our study to consider enrolling their children in public school. We describe these themes in further detail in the remainder of this section.

### *Motivations for homeschooling*

Each family described the reasons for homeschooling their children. These reasons included, but were not limited to, family values, religious philosophies, logistical complications, educational options at matriculation age, and negative experiences in traditional classroom settings. The following quotes express their motivations for homeschool:

*We began just with the thought that it would be best at that time for Fred specifically, and really our options were not optimal. The options that we had in our community. While you can do school transfers, the school that was nearest us was, and currently is, a school that is constantly having... It has some troubles, certainly, and it would not be the optimal educational experience for him. – Fred's mom*

*He went to a kindergarten co-op thing which was great, and we loved that. And then we homeschooled him for first grade. He wanted to go to school so he went to public school in 2<sup>nd</sup> grade and he hated it. And I think if you wanted to know why he hated it, he found it very stifling. School is about; sit down and do what you're told to do. The school that he'd had before, this co-op place, was a very child-centered. Like, "What would you like to learn today?" Self-directed kind of, and that's certainly how we do things at home. So he's been home since then. – Nelson's mom*

*When I was a young adult I was in a church where people were primarily home schooling. And I was in it long enough to see the long-term results. And what I saw was the flexibility that we had, and I liked the product. I was there are enough that I could see the kids grow into high school and I thought, "Ah, these kids are very well rounded. They're not very peer-dependent." What we wanted to get away from was the peer issues. – Alexander's mom*

*...if I'd wanted to enroll him in kindergarten the following year when he would have turned five in August, the cut off was August 1<sup>st</sup>, for the age. So he would have been not only way advanced than his peers, he would have been the oldest kid in the class and was doing, at that point, 4<sup>th</sup> and 5<sup>th</sup> grade reading and work. And there was no way I wanted to put him in that and make him bored or slow him down. – Kai's mom*

*But really I decided to home school so that he could be at his own pace. So that he could learn really fast in some things and take whatever time we needed in others. – Kai’s mom*

*...in school he would sit and read the books he wanted to read during class time and then bring his schoolwork home with him. [laughter] So he was doing double homework every night, after having a frustrating experience in the school hours.” – Marcus’ mom*

Homeschool families recognize that homeschooling provides their children access to opportunities they may not have in school. For example, Rick’s mom recognized the lack of engineering in traditional schools as a primary motivation for homeschooling.

*There’s not a huge engineering component to any of the schools he has been in. When we homeschooled, we did a lot of it because that is what RICK was interested in. – Rick’s Mom*

In general, the homeschooling parents who participated in this study did not state explicit learning goals associated with engineering for their children. They did demonstrate a deep commitment to educating their children in areas related to their interests that are both connected to and beyond their expertise. Fred’s mom says, “If it’s something that he enjoys, then we, as a homeschooling family, we need to find ways to support that interest and that education.”

Many other parents expressed similar levels of commitment to allowing their child’s interests to direct his or her learning experiences.

*...our main goal is to give them a really well rounded education and while also covering their passion and interests. So we really try not to leave any stone unturned. I mean, there’s not much that you could present to us that we wouldn’t be excited about, or try to whatever degree to run with, just to make sure that we weren’t leaving any stone unturned. – Theo’s mom*

### *Homeschool philosophies of families*

The ten families practice a variety of homeschool philosophies, including but not limited to, classical, traditional, Socratic, literature-based, unschooling, eclectic, and virtual public models. These are described briefly below.

Classical education is a process that takes students through phases in learning, called the “grammar,” “logic,” and “rhetoric” stages. Students learn vocabulary, engage in dialogue, and apply what they have learned in writing, teaching, or problem solving. It often involves the study of classical literature and Latin [10]. The traditional method uses traditional textbooks and workbooks to guide the curriculum [11]. The Socratic method [12] is a more specific component of classical or traditional education where dialogue and questioning is the method of learning. Literature-based philosophies do not use textbooks or workbooks, but instead historical fiction and first person accounts, as well as books written by people with a passion for a subject. Unschooling is a method of homeschooling coined in the 1970s by John Holt [7, 8], where learning is self-directed and parents find resources that help their children navigate within their

natural environment. Eclectic homeschoolers employ an intentionally diverse set of materials and philosophies to educate their children. They might use textbooks, workbooks, and unschooling all within the same year. Virtual public school students have a curriculum and a teacher who is not their parent. Table 1 shows the homeschool philosophy of each family in the study. We categorized each family based on their individual stated classifications, so families that are *unclassified* are families that did not name any particular philosophy or method.

**Table 1 Study Participant Homeschool Philosophy**

| <b>Student</b> | <b>Homeschool Philosophy</b>  |
|----------------|---|
| Rick           | Virtual Public  |
| Marcus         | Eclectic (with classical and textbook approaches playing prominent roles) |
| Tiffany        | Unclassified  |
| Theo           | Socratic  |
| Kai            | Unschooling   |
| Fred           | Unclassified  |
| Nelson         | Unschooling   |
| Matthew        | Unclassified  |
| Alexander      | Literature-based, traditional   |
| Elizabeth      | Virtual Public  |

*Characteristics of homeschool children in this study*

The homeschool students in the study are self-motivated, independent learners. There are a wide range of self-directed projects that these students have taken on. Tiffany, for instance, decided to plan the family garden. Before going outdoors, she used software to design the garden and then she mapped it out with tape. Rick wanted to build model airplanes, but he didn't want to use instructions. So instead of buying a kit, his parents purchased foam. He also voluntarily decided to take chemistry and physics in summer school. Nelson built remote-controlled robots. Marcus tried to design a fusion reactor that used magnets. He reports, "I didn't know if it would work in real life because...I was afraid that the plasma might get pushed back instead of actually compress...I designed it on paper. I didn't have enough powerful magnets to do it."

When interested in something, many of the homeschool students use their free time to go beyond their assignments or to further practice the skills they have gained, even to the point that their parents do not need to set standards for some subjects because their children achieve them independently. Fred reads textbooks in his free time so his mom does not have to include them in her teaching. Alexander programs on his Arduino microcontroller and built his own computer, after selecting and buying the individual parts. Alexander's mom reports, "So I would say he's a self-directed learner. We don't do a lot of those [technology] things in school because he does them spontaneously." Elizabeth's mom describes her daughter's motivation in day to day activities, saying, "We were just today out at Tractor Supply to look at the little baby chicks and all she kept saying was, 'We could totally build this chicken coop. We wouldn't even have to buy one. We could just build it.'"

*Parents' successful identification of appropriate resources for supporting engineering learning*

As previously mentioned, the homeschooling parents who participated in this study generally did not state any explicit learning goals associated with engineering for their children. Instead, they are committed to a broader goal of enabling their children to pursue their own interests, and develop knowledge and skills in whatever those interest areas might be, which, in this case are engineering-related skillsets and bodies of knowledge. These parents invest much time and energy in providing a variety of creative, educational opportunities for their children that ultimately help them learn engineering-related knowledge and skills. These include websites, toys and kits, and informal engineering programs, the most popular of which are 4-H, Girl Scouts, Boy Scouts, and FIRST LEGO League. Through these programs, children are able to build rockets, do basket-weaving, complete electrical projects, compete in robotics competitions, and program computers. Homeschool students also access engineering through peer experts (other young people within five years of age whom students use as resources to learn from or partner with on projects), who have engaged them in computer science, computer hardware, and automobile mechanics. For instance, Fred's mother describes her son's peer expert and their interaction, saying, "There's a teenager who is really interested in computer[s] and so [Fred] and this teenager have taken a computer from...a computer salvage store...and have reassembled it. This is something this child had done before and has actually done repeatedly, and so...he was showing [Fred] how to do it."

Many parents also support their children's learning by participating in homeschool cooperatives with expert teachers. Many also do a lot of research to find courses or programs at local universities that will give their children exposure to engineering and offer expertise in particular subject areas. Parents report that these courses and outreach activities are "optimal" for homeschool children who study advanced subjects.

Additionally, homeschool children have private tutors (individuals with some expertise, who may or may not be paid to offer tutelage or mentoring). Nelson recalls, "I've taken apart a car's engine [Chevy 56] and [my grandfather's friend Mark and I] built it again. I had to rebuild the whole thing." Tiffany learns new techniques from a young woman who does basket-weaving. Fred takes private lessons in computers from a local graduate student. Homeschool children also participate in engineering learning experiences through magazine subscriptions, building materials (e.g. K'NEX, circuits), books, camps, and other one-time events. A list of the resources accessed by the homeschool students is presented in Table 2, with a more comprehensive list presented in Appendix B.

In addition to the experiences listed above, parents also find resources by attending annual homeschool conventions and going online to find teacher websites for class projects and online courses (some age related, others university level). These online projects and courses, however, do not provide their homeschool students with access to peers with whom they can do the projects. As Fred's mom relays, "I think [the online course] certainly inspired him with ideas...but, it didn't come along with...a group of kids for him to do things with. I wish we had that."

**Table 2 Examples of Engineering Education Resources Accessed by Homeschool Students**

|                           | <b>Examples</b>  |
|---------------------------|--|
| <b>Activities</b>         | 4-H<br>Girl/Boy Scouts<br>FIRST LEGO League<br>Computer Programming<br>Camps           |
| <b>Physical Resources</b> | Legos<br>K'NEX<br>Arduino Microcontroller<br>Magazine Subscriptions                    |
| <b>Computer Resources</b> | Websites<br>Online Courses   |
| <b>Social Resources</b>   | Peer Experts<br>Private Tutors<br>Family Members                                       |
| <b>Events</b>             | Visit to a Science or Children's Museum<br>Lego KidsFest<br>University Outreach Events |

*How and what the study participants learn about engineering*

The study participants learn about engineering through the practice of building, creating, and designing. Some of the students generate their own ideas and then construct prototypes, while others follow directions to complete projects. Though they might not consider it engineering, students are engaging in engineering processes and applying mathematical and scientific concepts to accomplish their goals (see Table 3 for examples). In the building process, they encounter constraints, such as not having enough pieces or the right piece (Nelson, Fred and Kai experienced this while designing and building Lego structures), and then must apply problem-solving strategies through testing and experimentation (such as Rick's experience with designing and building rockets). They are often also learning the use of tools (such as Elizabeth's experience using hand tools under her mother's supervision). Some participants also learned programming skills. Kai's experience with Lego Robotics is an example of this. When asked what he learned from participating in an informal learning experience, Kai responded, "Well I did learn how to program Lego Robots."

Some of the children are learning very hands-on, practical skills as they engage in engineering through informal experiences, while others are wrestling with conceptual ideas. Alexander is active in 4-H, and he has done many projects in electricity. Marcus has a great interest in physics, and learns most of his engineering ideas from his participation at local university outreach programs and his interaction with tutors and experts. In Table 3, we share two examples of what students or parents reflect on as their learning, and include an interpretation of the concepts or skills they have learned.



**Table 3 Examples of What Engineering Content and Skills Students Are Exposed through Informal Activities**

| <b>Name</b>                                      | <b>Alexander</b>  | <b>Marcus</b>  |
|--|---|--|
| <b>Activity</b>                                  | 4-H   | University Physics Outreach  |
| <b>Student's/Parent's reflection on learning</b> | “Well, 4-H is where I learned some of the electrical, building electrical things. The first one was an on/off switch for a light. And the second one was a shake light, where you shake it and the light turns on. And then the third one was a trouble light. And then one we’re doing this year is a lamp.” | “Physics department had an open house in November...The open house was for all ages, so they had a lot of stuff set up for kids, like experiments on different physics topics, but there were some things that they offered for just like high school or college or adult. And one of those was a lecture on the new proof that...Higgs Boson really exists. And Marcus sat in on that lecture...And afterwards he said, ‘That was the best part of the open house. I learned so much about Higgs Boson.’” |
| <b>Our interpretation of what they learned</b>   | Circuit theory, wiring,   | Physics, Higgs Boson   |

*Need for resources to support older children*

Although parents have been successful in accessing engineering resources, as their students enter middle school and progress towards high school, they expressed anxiety about being able to continue to adequately support their children’s education. In the interviews conducted to date, parents have contrasted their experiences with finding resources when their children were elementary-aged with their experiences as their children approach high school.

*I felt like I wasn’t as intuitive about finding things for him to do that were going to get him into that mindset. You know, the kind of problem solving mindset, the kind of way of thinking about problems that an engineer would need to have...It’s not self evident to me what kinds of activities to do that are going, I guess, enrich his life in a way that will make engineering feel possible and interesting, and give him a sense of what the opportunities were. – Theo’s mom*

Based on responses to our parent survey, among the ten parents who participated in the study, half of the parents felt that they understood what engineers do well enough to explain it to their child, while the other half indicated that they could not. In particular, those parents who were primarily responsible for homeschooling their children and did not have a background in science or engineering expressed concern about their ability to continue to support their child in his or

her evolving interest in science or engineering. Fred’s mom says, “Because I’m not an engineer, I don’t know the optimal way to teach engineering.” Matthew’s mom, an elementary education major, expressed this very strongly: “I avoided science at all costs. I never even dreamed of doing anything engineering.” Sometimes parents can find a coop where another homeschool parent has a strong background in science or even engineering. However, the availability of another parent or expert can fluctuate from year to year. As Matthew’s mom explains their experience:

*Oh, we got a couple of science, actually PhD science, moms in our group, which is amazing. And so, there are some other people. Last year, we did science together, which was wonderful.*

Beyond not always knowing how to find the right resources – or not knowing if the resources would be effective in helping their children develop engineering knowledge and skills—parents in this study also discussed difficulties in finding other children interested in engineering for shared learning experiences. This is particularly important for engineering education since developing teamwork skills is a core part of engineering.

*For our particular community right now we’re finding that there simply aren’t that many junior high school kids that we have the option to do this with. – Fred’s mom*

Finally, parents commented on having more difficulty in finding informal learning programs for middle-school aged children compared to elementary aged children:

*When he gets to be the age he’s in now, once you get into middle school, there aren’t too many opportunities outside of the classroom, outside of an organized school, that I have found. – Nelson’s mom*

In summary, the homeschool parents in our study invested time and efforts into finding resources to support their children’s engineering learning, but finding these resources has become increasingly difficult as their children approach high-school age. As we begin to collect our year 3 interview and survey data, we will further investigate the extent to which finding resources for older children (i.e. 7<sup>th</sup> grade and above) is a concern.

## **Conclusions**

Homeschool families in this study are experiencing considerable success in finding creative ways that enable their children to pursue their own interests. They invested time and energy into finding a rich array of resources that support engineering learning. Through these informal learning experiences, these homeschool students have acquired engineering conceptual knowledge and skills, including but not limited to, the design process and mathematical and scientific theory. They have applied knowledge to solve problems, respond to constraints, and done research to design conceptual and physical objects with the resources they have and their parents have found.

It is important that we, as an engineering education community, keep this demographic of learners and agents in mind as we consider pre-college engineering education. We can learn from

both the processes that homeschool families have used to access the resources, as well as the resources themselves. This will help us to elucidate the many different options that are available for today's families in supporting the development of their children's engineering knowledge and skills in out-of-school settings.

The preliminary findings from this study raise interesting questions for future exploration. In the current study, we did not explicitly ask the parents about their goals for what their children would learn about engineering. We also did not ask them to provide specific details about the websites, museums, and other informal engineering resources that they (or their child) accessed (for instance, specific parts of a curriculum they used or which museum exhibits they visited). Nor did we find out the concepts that they learned from those informal learning experiences. These all present new opportunities for investigating student experiences in engineering education.

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## **Appendix A-1: Student Interview Protocol**

### **1. Icebreaker**

Let's start by talking a bit about you.

How many brothers and sisters do you have? What kinds of things are they interested in?  
*NOTE: These are intended as warm up questions, just to get the interview underway, and can be followed up with a few other "small talk" questions, like "What kinds of things are your friends interested in?"*

### **2. Questions about student**

How would you describe yourself to someone who doesn't know you?

What things are you interested in?

What kinds of things are you good at?

What kinds of things do you think you're not so good at (that you would say "that's not my kind of thing.")?

### **3. School courses**

Now let's talk about your school.

How long have you been homeschooled?

What's do you think is different about homeschool than going to a school building classroom?

Can you describe a normal homeschool day for you?

Which classes/subjects do you like the most? What is it about XYZ that is interesting to you?

Which classes/subjects do you like the least? Why?

Since the beginning of the school year (2011-2012), have you done any of the following activities? I want to know if it was in school or outside of school. (NOTE: Activities you did as part of a school club or afterschool program – we put in the outside of school category.)

|  | <b>In School</b> | <b>Outside of school</b> |                         |            |           |                         |
|--|------------------|--------------------------|-------------------------|------------|-----------|-------------------------|
|  | <b>Yes</b>       | <b>No</b>                | <b>I Don't Remember</b> | <b>Yes</b> | <b>No</b> | <b>I Don't Remember</b> |
| Visited a science museum, planetarium or environmental center?   |                  |                          |                         |            |           |                         |
| Watched a TV show, webisode or DVD related to designing, creating, or building?  |                  |                          |                         |            |           |                         |
| Used websites that contained games and/or stories related to designing, creating, or building (such as Design Squad Nation or Engineer Your Life)? |                  |                          |                         |            |           |                         |
| Played a computer game (such as SIM City or Minecraft) that was about related to designing, creating, or building?                                 |                  |                          |                         |            |           |                         |
| Read a book about designing, creating, or building?  |                  |                          |                         |            |           |                         |
| Played with engineering-related toys (such as Legos,   |                  |                          |                         |            |           |                         |

|   |  |  |  |  |  |  |
|---|--|--|--|--|--|--|
| K'NEX, robots).   |  |  |  |  |  |  |
| Took apart things (such as motors, computers, toasters) to see how they work?   |  |  |  |  |  |  |
| Participated in a competition to design, create, or build something?  |  |  |  |  |  |  |
| Participated in an activity where you designed, created, or built something, <i>as part of a school club, after school, or summer camp?</i> |  |  |  |  |  |  |
| Participated in a math club or camp, <i>as part of a school club, after school, or summer camp?</i>   |  |  |  |  |  |  |
| Participated in a science/technology club or camp, <i>as part of a school club, after school, or summer camp?</i>                           |  |  |  |  |  |  |
| Participated in a robotics club or camp, <i>as part of a school club, after school, or summer camp?</i>                                     |  |  |  |  |  |  |

Can you please tell me more about XYZ that you did in school?

Are there any courses or activities you hope to be able to do now that you are in middle school that you couldn't do in elementary school?

**4. Extracurricular interests & activities**

Now I'd like to hear more about your interests outside of school.

How do you decide what is school and what isn't school?

What do you like to do when you are not in school? [Probe for further details on what the participant likes or dislikes about the activity, why they choose to engage in the activity, etc.]

What else do you like to do with your free time? [Probe for further details on what the participant likes or dislikes about the activity, why they choose to engage in the activity, etc.]

Please tell me more about XYZ activity that you did.

Are there any (other) clubs, groups or organized activities you are a part of? [Explore further for each group (or, if there are a lot, for what the participant would say are the "most important" ones)]

What types of things do you do with [club/group/organized activity]? [Probe for the type of role the participant has played in the organization; why the participant was interested in the organization; what they like and don't like about it]

What have you learned through your participation in XXX activity?

Are there activities that you would like to do or might like to do, but you haven't? Which ones and what are some of the reasons you haven't been able to do them? [Probe for barriers]

## **5. Interest, expectations, and barriers related to engineering activities**

[If not already mentioned] Are you interested in designing, creating, or building things? How about problem-solving?

If so, can you describe the kinds of things you might like to do? What have you designed? Where do you do these activities? Do you do them with others or by yourself?

[If not already discussed] Would you consider yourself good at these types of activities? If not, why not?



What aspects of designing, creating, and building things are interesting to you?

How do these activities help you? (What do you “get” out of doing these activities?)

If not, what aspects of these activities do you NOT like? [Probe for potential barriers]

Where have you learned about designing, creating, and building, if anywhere? [Probe: school; hobbies/clubs/etc. – activities mentioned earlier. Also probe for kids who are interested but haven’t learned about it anywhere to get at barriers]

Would you like to learn more about designing, creating, or building things? If so, how do you think you might do that? [What activities would they choose to engage in? If not, try to learn what’s preventing them from doing those activities, if anything.]

## 6. **Understanding of engineering as a career**

Now I would like you to picture someone with a job where they design, create, and build things. What comes to mind when you think about this person? What do they look like? [Probe for characteristics of engineers as well as ideas about what the engineer does]

[If student has not already used the term engineering] If an adult did that kind of work (designing, creating, and building) what would you call that? [Don’t use the term engineering--use their own terminology.]

Do you know anyone with a job like that? [If yes: have them describe what those people do]

What do you imagine people with these jobs do on a day-to-day basis?

## 7. **Future plans**

Even though graduation is pretty far away, I’d like to get a sense of your future plans.

What do you want to be when you grow up?

How did you choose (xxx)?

Have you considered other areas/subjects?

How would you become a (career choice)?

What would you say it takes to be a good (insert student's career choice)?

How are you at (insert characteristics student mentions)?

Are there any fields/careers you just don't want to go into? Why?

Who talks with you about career choices (parent, relative, teachers, etc.)?

(If applicable) Do you have any mentors (adults you can look up to) in the career that you are interested in? If so, please tell me about them.

## Appendix A-2: Parent Interview Protocol

### Homeschool Parent Interview (Year 1, In-person)

In this interview, I am hoping to learn about your child's interests in and outside of school. I'm also interested in learning about the things you do together and the hopes you have for your child's future career someday.

1. **Learning about the student** (If the child is sitting with the parent and you have just asked the child to describe themselves, modify these slightly so it doesn't sound like you are trying to verify what the child just told you)

First I would like to get a sense of who your child is.

What characteristics best describe your child?

What are some things that your child is good at?

What are some of your child's interests?

What do you do for fun with your child?

What does your child like to do for fun alone or with friends?

Are there particular qualities or interests that differentiate [child's name] from his/her peers?

Academically, how does [child's name] perform compared to his/her peers? [Probe for strengths, weaknesses]

2. **Homeschool**

Please tell me your homeschool story. (Probe for reasons, length of time, philosophy, etc.)

What is your educational background? (Be sure that you get info on undergrad major and any certifications or special training.)

How do you distribute the teaching? Do you participate in a co-op or have others teach certain subjects? Please describe your system.

What is your teaching approach? [Probe for whether teacher uses inquiry-based approach or something else]

How much do you incorporate hands-on activities into your classroom? Please describe.

Which curricula do you/have you used?

As you know, sometimes kids feel negative pressure from their peers if they show an interest in science, technology, or math. When do you see this type of pressure amongst kids at your co-op? Please describe. [Probe for differences between boys and girls]

### 3. **Student activities**

Has your child participated in any summer camps or after school programs focused on {interest}?

Please tell me about those experiences.

Are there any other activities that your child engages in to learn about {interest}? [Other things to probe: science museums, video games, books, television shows, movies, magazines, websites, competitions.] (Probe each one of these separately)

### 4. **Student interest in designing, creating, and building**

[If not already mentioned] Is your child interested in designing, creating, and building things? [They should say Yes in Year 1, based on screening criteria]

What does your child like or not like about these activities?

[If child is not in the room] Would you say your child is good at these types of activities? [Lack of skill, or perceived lack of skill, is a potential barrier]

How does the child handle challenges, or difficult subjects?

Is [child] good at problem-solving?

[If the child is interested] Are there any particular things that you or someone else in your life does to help your child learn about designing, creating, and building? Things that you talk about together or do together? Please describe.

[If not already mentioned] Has your child participated in any summer camps or after school programs focused on designing, creating, or building? Please tell me about those experiences. [Probe for how the child gets involved in it, and potential barriers to student enjoyment of the experiences.]

Does your child have any other hobbies that involve designing, creating, or building? Please describe.

Are there any other activities that your child engages in to learn about designing, creating, and building things? Please describe. [Other things to probe: science museums, video games, books, television shows, movies, magazines, websites, competitions.]

## 5. Parental support for engineering

What do you think about your child's interest in designing, creating, and building things?  
[Probe for whether they approve or not or support these activities.]

How do you talk about future jobs with your child?

If your child wanted, today or in the future, to have a job where they designed, created, or built things for a living, how would you feel about that?

Would such a job be a good career path for your child? [why/why not] [probe: is it because parent doesn't like engineering? Because parent doesn't think the child has the right interests? Child doesn't have the right skills?]

What other jobs or careers can you see your child doing in the future? [probe to understand why – child's interests, skills, etc.]

Do you think middle school should teach kids how to design, create, and build things?  
[why/why not]

(Potential follow-up) When do you think kids should learn how to design, create, and build things?

## 6. School

Which specific lessons or components of your curriculum match well with [child's name] interests and skills?

Do you include design, creating, or building activities in the content that you teach?

[If so] What types of activities?

[If so] Are you using the term engineering when doing designing, creating, or building activities in class?

[If not] Why or why not?

How do you tie such activities to real-world examples? Please describe.

Do you ever bring in outside experts, role models or mentors to teach the kids about these topics? Please describe.

## 7. Parental understanding/perception of engineering

How do you think engineering is different from science?

How do you think engineering is different than design?

8. **Wrap-up**

As we finish, I would like to get a sense of whether there is any additional information that you would like to share? Are there any questions you would like to ask me?

[Collect the name of the child's teacher and any informal educators we should interview.]

## **Appendix B: Comprehensive List of Resources**

### **Television Show**

Design Squad

### **Robotics**

FIRST LEGO League

Junior Lego League

### **Websites**

Design Squad

Engineer Your Life

Code Academy

Khan Academy

NASA.com

NASA.gov

Lego.com

superchargedscience.com

Hackaday.com

OpenTTD.com

### **Museums**

WonderLab Museum of Science, Health,  
and Technology

Smithsonian Aerospace Museum

Indianapolis Children's Museum

Houston Space Center

LA Planetarium

Lilly Nature Center

Museum of Science and Industry

### **Girl Scouts/Boy Scouts**

Legos

### **4-H**

Electricity

Computers

Rocketry

Small engines

Aerospace

Astronomy

4-H Roundup - an engineering career day at

Purdue annually

Basketweaving

Junk Drawer Robotics

LEGO MINDSTORMS

### **Software**

CAD Program

Arduino

### **Computer Games/Video Games**

The Way Things Work

Minecraft

Zoo Tycoon

Minetest

### **Books/Magazines**

The Way Things Work

Aviation Magazine

Science Explorer

MAKE (ASK when younger)

LEGO Magazine

### **Curricula**

Gateway to Technology

Super Charged Science

The Great Courses ("The Great Structures")

Junk Drawer Robotics

### **University programs**

Rose-Hulman

Rose Hulman engineering expo (3x year)

Nano facility (Purdue)

Innovation to Reality @ Purdue

### **Toys**

Mythbusters kit