Family Engineering for Families of Elementary-Aged Children

A Review of the Potential Impact

Jenifer V. Helms

Heather Mitchell

Michelle Phillips

Mark St. John

June 2012
INVERNESS RESEARCH

Table of Contents

Purpose and Audience

The purpose of this report is to provide an external review of the Family Engineering program and its potential value. This report is summative in that it provides assessments of the overall utility and value of the Family Engineering curriculum; it is "early" in the developmental lifetime of Family Engineering in that much of it is based on data collected prior to the launch of the final product.

The audiences for this report are people interested in implementing Family Engineering programs in different settings, people interested in engineering education more broadly, potential funders of family engineering programs, and the larger STEM education field.

Introduction

Engineering is increasingly becoming a priority in STEM education. In May 2011, the Engineering Education for Innovation Act, or E^2 for Innovation Act (HR 1951), was introduced, which "authorizes the Secretary of Education to award planning grants and matching implementation grants to states to integrate engineering education into kindergarten through grade 12 (K-12) instruction and curricula."[1] A 2009 publication of the National Academy of Engineering and the National Research Council stated that while engineering programs are not prevalent in K-12 classrooms, they do have the potential to "improve student learning and achievement in science and mathematics; increase awareness of engineering and the work of engineers; boost youth interest in pursuing engineering as a career; and increase the technological literacy of all students" (Katelin, L. et al, 2009).

There is ample evidence demonstrating the positive effect family involvement has on student achievement and development (Henderson, 1994 and 2002; Weiss, 2006 and Ferguson, 2008). Research has demonstrated that students are more motivated to learn and develop positive attitudes about school when their parents are involved in their education and that this is true across different socio-economic and cultural groups (Weiss, 2006). The Family Math and Family Science programs were developed in the 1980's and 1990's, respectively, to support children in developing strong foundations in math and science, to encourage them to consider these fields for their future careers and to help build lasting connections between school and home.

There are few published reports of the outcomes of these two popular programs but informal reports from program leaders suggest that attendance at a series of Family Math or Science events offers rich benefits to both families and children. For example, after attending a series, many parents continue to stay involved in the school, families and children felt more confident in their

[1] See http://www.opencongress.org/bill/112-h1951/show.

abilities and engaged more frequently in discussions about related topics at home (Coates, personal interview 2012).

Family Engineering builds on the foundation of Family Math and Family Science by offering families the chance to explore engineering concepts and careers in a manner that is accessible and engaging, and in doing so, aims to build STEM-related skills and career aspirations as well as connections between school and home. In an effort to bring engineering education to families, the *Family Engineering for Parents and Elementary-Aged Children* project partners the Foundation for Family Science & Engineering, Michigan Technological University, and the American Society for Engineering Education (ASEE). Drawing on the lessons learned from Family Science and Family Math, the project leaders created a guidebook for facilitating family engineering events in a range of settings.

What, exactly, is engineering for families? According to the project, an effective [engineering] activity [for a family] is one where the family spends the majority of their time doing rather than listening to a presenter, and one that relates well to their own personal experiences in some way. Further, with respect to the importance of parents in children's learning, the original project proposal stated,

> *While much attention is focused on creating highly-qualified teachers, it is essential that parents are on board when it comes to supporting their child's choice to pursue math and science in secondary school and, ultimately, STEM fields as a college major. Numerous studies have found that college students and young adults cite parents as an important influence on their choice of career.*

The *Family Engineering for Parents and Elementary-Aged Children* project sought to create a resource book to support the delivery of a family engineering program or event that would increase young students' and their parents/caregivers' interest in, understanding of, and confidence in doing engineering, as well as build the capacity of formal and informal educators, engineering professionals, and other relevant groups to facilitate family engineering events.

Stated formally, the goals of the Family Engineering program were as follows:

- Engage families in engineering with fun, hands-on activities;
- Increase public understanding and appreciation of the role engineering plays in everyday life;
- Introduce children at an early age to the many career opportunities in engineering;
- Increase parents' interest in and ability to encourage their children to pursue an engineering career; and

- Provide age-appropriate resources to support volunteers in conducting informal engineering education programs with elementary-aged children and their parents.

The book, titled Family Engineering: An Activity and Event Planning Guide, was published in the summer of 2011. The fruit of the collaborative partnership, the guidebook includes background information about family learning, education standards, the engineering design process and common engineering fields, and suggestions for how to plan and implement a family engineering event. The majority of the publication consists of detailed instructions for implementing a range of engineering activities and design challenges. The target audience for this publication is individuals who are interested in hosting or facilitating a family engineering event—primarily educators, engineering professionals, and informal educators, and secondarily parents.[2]

This report, prepared by Inverness Research, provides a summary overview of the development of the Family Engineering program, the potential of the program to impact a range of participants, and its potential to impact STEM education more broadly. For details about our data collection sources and methods, please see Appendix A.

The Development of Family Engineering

In 2010, the project conducted field-testing of the engineering activities that would ultimately comprise the guidebook. The lead partners selected eight organizations across the country to conduct five Family Engineering events, each, within a three-month time frame. David Heil & Associates (DHA) collected extensive data from families and facilitators, for the purposes of improving and refining the individual activities, as well as other aspects of the events. In addition, engineering and education experts conducted extensive reviews of the activities in late 2010 and early 2011.

The formative evaluation helped the book developers identify activities that were problematic for either the families or the facilitators, or simply did not work well in a family setting, in addition to identifying activities that worked well. The formative evaluation also helped the project identify issues related to planning, recruiting for, and facilitating an event that would be addressed in the final product. For the most part, all of the activities tested were quite well-received by families and event staff and volunteers—as stated in DHA's formative evaluation report, activities given the lowest ratings were still rated quite positively by more than 80% of participants.

According to the formative evaluation report, activities with "real-world" application were rated highly, while activities that had difficult facilitation

[2] One PI noted that clarity of audience was a critical starting point for the project, which helped "keep the focus on who we were writing to."

steps, or ineffective materials were rated lower. Areas that emerged as needing further development and support at the time of the field tests included facilitators' ability to recruit participants for an event, narrowing the target family audience age range, selecting the right venue and audience size, developing event schedules that allow enough time for families to complete and debrief their experiences, and ways to measure the impact of the event on the families.

Overall, the events were quite successful in increasing interest and awareness in engineering. Following the final field tests, the partners held several meetings in person and on conference calls, and narrowed the final selection of the activities, as well as the content for all of the introductory and background material. They published a final version of the book in July 2011, with 10,000 editions in English and 1,500 in Spanish printed.

The Potential of Family Engineering

In the following sections we discuss the potential of the Family Engineering program and guidebook to achieve the project goals stated earlier and repeated here:

- Engage families in engineering with fun, hands-on activities;
- Increase public understanding and appreciation of the role engineering plays in everyday life;
- Introduce children at an early age to the many career opportunities in engineering;
- Increase parents' interest in and ability to encourage their children to pursue an engineering career; and
- Provide age-appropriate resources to support volunteers in conducting informal engineering education programs with elementary-aged children and their parents.

The Organization of This Report

First, we discuss the **quality and value** of family engineering as reported to us by a wide range of people with different perspectives: field test facilitators and families who attended their events, families who attended non-field test family engineering events, people who have purchased the book since publication, PIs, and advisors. Then, we highlight issues related to **logistics and feasibility** of orchestrating family engineering events, and finally we report the **range of contributions** of the program to families.

Our Research

As noted earlier, DHA conducted field tests in which extensive data were collected from families and facilitators for formative information about the activities and the events overall. Inverness Research observed one field test event, as well as three other Family Engineering events that were arranged by project leadership. At these events, we talked with families, interviewed facilitators, administered an exit survey, and conducted follow-up telephone interviews several months after the events. In addition, to date we've conducted telephone interviews with six people who purchased the book, and surveyed an additional 28 people who purchased the book. Throughout the remainder of this report, we highlight findings from the field tests conducted by Heil & Associates where appropriate, but primarily we report on findings from the data collected by Inverness Research.

A final note about our sample sizes: due to the timing of the publication of the book and the completion of the grant period, we were limited in the number of people we were able to survey and interview regarding their interactions with the final published version of the Family Engineering guidebook. While the survey from both the families and the book purchaser survey findings may not represent statistical significance, the large majority of what we learned from the family surveys was not contradicted by any other data we collected. In other words, what we heard from families was quite positive; and while some overwhelmingly-positive comments were made by just a few individuals, we did not hear any comments to the contrary. Further, the sample of families we surveyed and interviewed represented a wide range of facilitator roles and host settings, which are characteristic of the range of audiences the project is hoping to reach.

Quality and Value of Family Engineering

The Family Engineering leadership team had the advantage of including people who a) had experience with the development and publication of the Family Science guidebook, and b) had extensive experience conducting Family Science programs and events. In particular, the group's expertise with family learning, understanding family dynamics in a learning context, and the methods of instruction and materials that are effective all came into play in the development of the Family Engineering book. One PI noted that this expertise will "bear out to be an advantage in the long run for Family Engineering."

As noted earlier, throughout the field-testing process, participants rated activities quite high. At the four events Inverness Research observed, families were very engaged and interested in the activities in which they participated. While the size, venue, and format of each event differed, the level of engagement was consistently high. Exit surveys (N = 87) from participating families at three of the events indicate that families felt that the event was of high quality along several dimensions. We asked families to rate their agreement with statements about the event on a 1 to 5 scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). As the table

below suggests, the large majority of families found the event engaging and enjoyable for their family, and well organized. Importantly, about ¾ of families agreed that their ideas about engineers or engineering were different as a result of participating in the Family Engineering event.

Answer Options.	**1**	**2**	**3**	**4**	**5**
Our family enjoyed the event.	0%	1%	1%	30%	68%
The event encouraged our family to work together.	0%	0%	4%	35%	63%
Our family learned something new during the event.	0%	0%	4%	34%	64%
The event was engaging to everyone in our family, regardless of gender or age.	0%	1%	0%	36%	63%
The event was well organized.	4%	1%	2%	32%	61%
The event introduced us to activities we would do at home as a family.	0%	0%	13%	41%	46%
My ideas about engineers or engineering are different as a result of this event.	0%	4%	23%	39%	35%

Facilitators of the events we observed also praised the activities and event organization. The amount of information available to implement a family engineering event, and the background information contained in the publication proved to be more than sufficient for those who have hosted an event. One suggestion that was made by several facilitators as well as book purchasers was the desire to be able to download the signs and cards from the Internet so that they could be printed in color, as many schools do not have color copy machines.

Following the publication of the book, we contacted people who purchased the book to ask them about their motivations for buying the book, intentions for using the book, and their impressions of its quality and value. And, if they had already used the book to plan and host an event, the ways in which and the extent to which the book helped them to do that. We conducted six telephone interviews, and invited 89 people to complete an online survey. We received 28 completed surveys.

In terms of the quality of the guidebook, 100% of the survey respondents rated the book to be of high or very high quality. Some comments accompanying the ratings of the book include[3]:

Very impressive.

Outstanding level of detail. Everything I needed was in there.

Good activities and well written so a non-educator can use and understand it. Some of the activities are "classics" which is o.k. and some are new to me (which is unusual at this point in my career.) I particularly like the chocolate machine.

I am planning on using this book with my Science teachers at my school for a Family Engineering night in the fall of 2012. In addition, I will share this with my colleagues in my school district. Hopefully my school system will buy one for every elementary and middle school.

I appreciate the background information at the front of the book. The activities are well organized and the directions are clear. There are a variety of activities. I also appreciate the resources.

I really appreciate the step by step planning guides as well as the masters.

We love it. I sent my Science Teacher to additional training. She has my copy all marked up. We have gone through all the resources together and are very enthusiastic about our event on March 20th.

Excellent, clear directions and the appendix with the masters of all needed paper materials is great.

It would be even better if the book came with a CD of all of the printables.

[3] The quotes in this report have been lightly edited for clarity without changing the intended meaning of the speaker.

Survey respondents also rated the value of the guidebook very highly–89% rated the value high or very high. We also asked people to comment on what about the Family Engineering book was most useful to them. A sample of comments:

I love the fact that most of the materials are easy to access at a local hardware store or at Wal Mart.

I found the quality of the lessons and the depth of the background information sufficient to have a modestly comfortable staff member be successful in implementing the family experiences. The pre-made signage, materials lists and organizers so that we did not have to create these ourselves—WHAT A TIME SAVER!

New ideas for activities. The openers at a glance is helpful. List of supplies.

The pictures, step-by-step directions.

I used nearly the entire book. No complaints about it.

The suggested evening agenda and the project ideas.

The activities—all laid out nicely and ready to be used.

This book is a necessity when setting up a Family Science Event. It has definitely extinguished the fear that I had over this project. Many kudos!!!!

Actually, I think the entire book is useful—for different reasons. The front of the book helps build understanding and buy-in. The back of the book is the nuts and bolts. I need it all!

Descriptions of how to use supplies provided in the kit.

Training for events and school day use.

I think the book is a great overall resource in how to plan and implement an effective event.

Checklists, overall organization and suggestions.

Visual images and step by step instruction to make it transferable for others who may wish to use it later.

I would never have come up with the variety or the quantity of things for students to do. It is a bonus that you've provided clear instructions and support materials.

Finally, PIs and key advisors reported that they believe the published book reflects the rigorous field-testing and review process, and is a high quality product. The field tests were invaluable for helping the project leaders gather information about each activity as well as insights about what it takes to plan and host an event. The PIs and project advisors also valued the insights of the educators and engineers who conducted a critical review of later drafts of the publication. One PI said:

We valued both the educators and engineers who reviewed the drafts. The educators were helpful in terms of issues like what does the setting look like, how do we discuss procedures, etc. and then engineers were helpful regarding accuracy on the content and engineering side. They were all validating what we laid out. I think [the reviewers] were good about reading thoroughly and focusing, and made good comments. The educators looked at the pedagogy side, and engineers on the content, but both could cross those boundaries.

The rigorous review process, the PIs believed, will add to the appeal of the publication by those who are critical consumers of educational materials. Indeed, purchasers of the book praised the depth of detail and information included in the book. A principal of a STEM-focused elementary school—who learned about the Family Engineering book at an *Engineering is Elementary* professional development event—is particularly appreciative of the flexibility of the guidebook, in that she can imagine using it to plan a family engineering night, as well as pulling activities out to share with teachers to do in their classrooms.

Feasibility, logistics and supports for Family Engineering

The field tests of the Family Engineering activities took place in a range of venues, including community centers, schools, and science museums. In many cases, the events were conducted in conjunction with a university partner, where faculty or students from the engineering department participated in some way in the implementation of the event. Based on our observations and interviews with facilitators, there does not seem to be an advantage of any one particular venue—**the key to a successful event is having strong leadership, enough space for the number of participants one expects, and enough volunteers to guide families as they move through the various activities.**

As noted earlier, the Family Engineering guidebook seeks to empower those individuals who would like to facilitate a Family Engineering event—educators, engineers, engineering students, informal educators, families, and the like. Respondents to our online survey (people who have purchased the book) as well as our interviewees represent the range of roles within this target audience, with the exception of professional engineers. The respondents also represent a range similar to the field test venues. While the majority of respondents we contacted plan to hold events at a school (or have already done so), there are also events planned for a library, YMCA, community college, university, and science center. On the survey, we asked respondents to rate the extent to which they felt the book provides sufficient information about the supports needed to host an event. Eighty-eight percent (88%) of respondents agree to a great or very great extent that the book provides sufficient information about the supports needed. Interviewees responded similarly.

One key advisor to the project who is very well-connected and knowledgeable about engineering education believes the Family Engineering guidebook is a major contribution to the field that could be used in a variety of settings. She explained:

> *This publication provides a set of resources that can be used. I would not be surprised if there are other places that use the book other ways—in school, after school, etc. These are tested activities that can be brought into informal or formal settings. It is a program to reach parents, but it could be used as intended or used in other ways. It might trickle far beyond that, as there are not that many good engineering activities out there for people to turn to.*

Potential challenges to successful Family Engineering events

Feedback from field test sites, and facilitators of events we observed, suggests that recruiting participants may be the most challenging aspect of hosting a Family Engineering event. As one facilitator noted:

> *A major challenge for this program is generating interest. I have contacted schools I knew or have worked for in the past, because cold calls would be more challenging. Getting everyone on board, getting volunteers from the school, transportation, incentives—it all takes preparation, and time commitment for many people. But there is nothing better you can do than get a family working on stuff—they might have been dragged there, but when they leave, they've had a good experience.*

During an interview, one book purchaser stated that one of the major barriers to doing family events, especially for teachers, is the amount of planning and work it takes to collect and assemble all of the at-hand materials. This sentiment was also shared by a facilitator of an event we observed.

> *Obviously, in any of these types of events—and this is just me speaking from so many years working with teachers and doing these—and while these types of activities are done with at-hand materials or there are materials in the book that you can copy and create, teachers get a little bit bogged down in getting all of the stuff, and you need to get them*

all done correctly. Not that it is hard, but this is obviously one of the reasons why these types of events don't happen more, because you do have work to set it up.

Across sites, there was variation in terms of the focus of the event; whether it was on the content and processes of engineering, or simply having families engage in hands-on activities. For example, in some sites, the engineering design cycle was heavily emphasized, whereas at others it was not mentioned, or barely touched on.

Sites also varied in terms of the nature of engineers' involvement and impact at the event. The presence of engineers, for example, did not guarantee that the focus was on engineering practice or design, and in some other cases, engineers did not have experience or practice with communicating effectively with the public.

Interestingly, content or teaching expertise did not seem to be barriers for people we contacted about holding Family Engineering events. People who purchased the book felt that there is plenty of background and supporting information in the book for them to host an event. Whether or not there were people with engineering expertise available, the book provides very useful and understandable background information. And, even for people who are engineers or have engineering content background, the book helps them with pedagogical approaches they might not know about. One book buyer, who supervises undergraduate engineering students in outreach settings, stated in an interview:

The thing that I found with my staff is that the very explicit questions that should be asked are helpful. They have content expertise, and rightly they understand the engineering content, but maybe they don't understand necessarily the pedagogy side, how to explain something depending on the ages of the students, what types of questions are appropriate for what level. So they might have a kindergartener and they are trying to do a particular activity: what questions are appropriate for that student's development? So that is something that I have found—the more specific that I can be, especially with the idea of like scaffolding them for different ages and questions to ask intentionally, or strategies for teaching, the better. In the beginning [of the guidebook] they have something about parents, here are some strategies, don't give them the answer, etc. That is useful.

Family Engineering: Contributions to families

Book purchasers we interviewed stated that they hear over and over again in their communities that individuals who pursue a career in engineering do so mainly because of the influence of a family member who either is an engineer, or connected in some way to engineering and design. The project leaders also made this point in their original grant proposal. Our interviewees said it is important for families to have opportunities to learn more about engineering and what engineers do to be able to talk with children about engineering as a possible career path. This is especially true when engineering is rarely a part of

the K-12 school curriculum. As one interviewee, who works in university outreach, put it:

> *If you look at all of the research about who pursues engineering as a career, it is students who have someone in their close family, if not a parent, an aunt, an uncle, somebody who is an engineer. Otherwise people don't have a good sense of what it means to be an engineer or do engineering. They think, oh you have to be smart to do that. That is all they know. Seeing the types of problems that can be addressed, and the types of skills that are necessary, I think it is important not just for children, but also the family members to have a better understanding when a student says, I think I might want to look at this engineering school. Someone who doesn't know might say, why don't you look at something else, just because they are not sure what it entails. Providing more awareness as to what is really necessary in engineering education for elementary and secondary, the K-12 population is important. Schools are too slow to change, in terms of adding engineering. Also, [engineering] is not going to be part of the every day routine for everybody. I think the importance is helping people to understand what it means so that the students can make more informed choices with more knowledge, whenever they are looking at career areas.*

Data from the exit surveys of the events we observed indicate that families attended the event primarily because of their child's interest in participating. In fewer cases, the family wanted their child(ren) to have more exposure to STEM fields. The table in the section above indicates that families believed they benefited greatly from the event. When asked in the exit surveys if they would recommend the event to others, 100% who responded did so in the affirmative. Typical reasons for recommending the event included statements such as: "It is educational and fun;" "A chance to learn problem solving;" "Very productive activities;" "Hands-on and creative;" and "It helps kids understand the process of thinking."

One facilitator with many years of experience in family learning believes that Family Engineering offers families an opportunity to interact in new ways, as she explains:

> *I tend to take for granted what is going to happen, but what is lovely is that folks are always excited at the discovery of something, and at the understanding of something or at the creation [of something]. When families have created something together in Family Engineering that succeeds, they are "high five-ing" each other and it is very cool, as you watch the family dynamic. When families discover an answer to a problem or a solution that works they are joyful, and it reminds me of the importance of the work. …When families learn and talk about things together, they change their dynamic for that moment—most of them are learners, and most of them are joyful at the discovery of the learning. I call it identity because I can't think of another word, but their identity as co-developers and co-discoverers is enhanced, and they see themselves as the problem-solvers, they see themselves as builders, they see themselves as potentially doing this in their life. Or, parents having a new vision of how their child thinks. I always hear this from parents, they say, I am really surprised at how deeply he pays attention, or how long he focused on this particular item or task. It changes how parents see their children and how the children see themselves.*

Another teacher with 25 years elementary teaching experience who coordinated an event for over 400 parents and students, believes that engaging parents and children together is particularly important in STEM areas, since many parents may or may not have had positive learning experiences in STEM. She explains:

> *I believe that especially at the elementary level, it is so important [to provide family learning opportunities] in STEM because people might be very uncomfortable with the subjects. In their own education, they might have had a bad experience, where it was presented in unpleasant way. That filters to the kids a lot. I hear parents in conferences say things like "I'm bad in math, that's genetic," and of course that has nothing to do with it. So getting them to understand it, to get excited, they will connect with the child. We have to educate the entire family, and I really see that in math and science… Also we have a lot of parents that are not educated and first generation, so to incorporate them and have them get excited and encourage the kids to do well in math and science, look what you can do… it's a great success.*

In our survey of book purchasers, we were interested in knowing the extent to which they hoped participants would learn about engineers and engineering from the events they hosted (or planned to host). All of the respondents—100%—hoped participants would gain excitement about engineering, and the desire to learn more about it. About three-quarters of respondents hoped participants gained knowledge about engineering and what engineers do from attending their events. Finally, just over 80% of respondents hoped that the event would provide an opportunity for participants to learn as a family.

In follow up interviews with families who attended one of the events we observed, or one of the field test events, we were able to get a better sense of what they learned at the event, and the impact the experience had on their families' beliefs and behaviors vis-à-vis engineering. The following sections report findings from these interviews.

What did families learn from the event?

When we asked the families what they and their children had learned from the event most of their answers fell into four broad categories.

- They learned that engineering is accessible;
- they learned about the design process and the problem solving process;
- they learned about the different kinds of engineers and engineering;
- they learned that engineering can be both valuable and fun.

The most common response was that the event had shown them that engineering is accessible. Families mentioned realizing that things they encounter everyday involve engineering. Other parents talked about how they now knew that simple activities could illustrate engineering concepts and that they could easily do these activities at home with their children. Similarly, families mentioned that they realized that children could learn about

engineering through play. The following quotes are illustrative of comments from families.

She learned that it is something that she can do, first of all, and that it is something accessible and I know in fact she just had a friend spend the night this weekend and they made a pulley system from the second floor to the first floor to send down messages and they referred to what they were doing as engineering.

It really got us thinking as parents, simple little things that we could do at home to demonstrate some basic science skills.

I think after that program, they might have thought, wow it could be a really fun career and something interesting and fun and it is not just all sitting behind a desk. I learned how to translate some of the concepts through play to my kids.

Especially with the big activity, the process of trial and error and modifying things. (For example) having flat little boards and trying to figure out where the fulcrum needs to be and playing around with it. I think, to me that was the biggest learning point, it is not always going to be right the first time. You got to put something together, try it out and if it doesn't work, try to figure out why it doesn't work.

Kids learned that there are lots of kinds of engineering. Before we went into the experiment, they talked to us and they interacted with the kids asking who would like to be this kind of person, who would like to build roadways and kind of explained to all of the kids the different areas of engineering that you just don't typically think about, like your bicycle, building your bicycle and it took an engineer to put that together.

How important is engineering knowledge to the families and why?

We asked families to rate the importance in their household of knowing something about engineering. On a scale from 1-10 where 10 represented the highest score—93% of families interviewed rated the importance of having some knowledge of engineering a 7 or above on a ten-point scale and 39% rated the importance of engineering a 9 or above. Families had a variety of reasons for rating the importance of engineering highly but the two most frequently mentioned were that someone in the family was an engineer and that families wanted their children to understand some aspect of engineering including possible careers in engineering. Families also thought it was important for their children to understand the skills related to engineering such as problem-solving, design, building, familiarity with materials and general math and science skills. Several of the families mentioned that engineering was important to their family because their child is really interested in it. The

following quotes illustrate the reasons families rated knowledge of engineering as highly important to their families.

My husband is a hardware engineer with computers and telephones and then, my children, it is just really important for them to figure things out on their own and problem solve. I am not going to buy them every gadget or every toy for their doll and so then they get cardboard and make it themselves.

I think it is important that the kids have an introduction to some of these careers and possibilities for them at a younger age and so that they can work towards something that fits or really catches their eye that they want to do.

I would like my daughter to be able to understand building things, about materials and thinking about design, structure.

It is important to me because I think it gives it an advantage to the kids who are exposed to it a little earlier. They start exploring the why of how things are. This is the reason why it won't blow over, or this is the reason that the ship doesn't sink.

Did attending the event increase the families' interest in engineering or how they think about engineering?

86% of the families interviewed said that attending the event had increased their interest in engineering and/or changed they way they thought about it. Families mentioned learning simple things they could to at home with their children, feeling that it was important to get children involved in learning about engineering at a young age and learning that women are active in engineering. The two most common responses were that the event opened their eyes to the nature of engineering and that the event awakened an interest in engineering in their child or children, through fun and accessible activities. The following quotes are illustrative of parent's responses.

Our daughter really wants to just be a princess and there were a lot of women there that were involved with the process. I think she identified with them working on the different activities with these different women. She enjoyed it and it wasn't such a boy thing to do, it wasn't like playing with her brothers.

It made me aware of all of these ways that engineering is used, all of the fields that engineering is used in, a very broad variety of things and I had no idea that engineering was as necessary as it is.

I think all of my kids learned that it can be fun and it is not just boring. I guess sometimes it seems to people on the outside.

Did attending the event increase the families' knowledge about engineers?

82% of the families interviewed said that the event had increased either their or their child(ren)'s knowledge about engineers. Overall, families' comments could be summarized as they now have a much better understanding of what kinds of people are engineers and the variety of work engineers do. Several families also reported that their children were more interested in what the engineers in their lives do. The following quotes are illustrative of parent responses.

> *Their uncle is a mechanical engineer and I know that the oldest one especially, but even the daughter have talked to him a little bit more about what he does and how he likes it.*

> *I think she originally thought about it as men with white hair and lab coats. She understands it in every day life as well. I was glad to see the different aspects of engineering and like I said, the amount of young woman that are becoming involved.*

> *We talked about it for awhile, both he and I gained a better knowledge of engineers and their responsibilities.*

Did attending the event increase the children's engagement in science or math?

More families reported an increase in engagement in math and science than those who reported none. 57% of the families interviewed said that the event had either increased their children's engagement in science and/or math or had reinforced their existing engagement. These families cited noticing that their children were more interested in doing their homework in science and math, expressing more interest in these topics and seeking out extra opportunities to explore these topics at school or through special projects such as science fairs. The following quotes are typical of comments from parent who had noticed a positive effect.

> *My oldest son, he has decided to take some more classes that are going towards engineering, well architectural or structural engineering.*

> *I think my daughter has been a little happier to do her math. I think it goes back to those girls that she met at the event and that she thought it was really awesome and cool for her to hang out with them. I think she identified with them.*

> *He loves science and that event kind of piqued his interest in science.*

Last week, the teacher sent home a science project that was optional for them to do and it wasn't for extra credit or anything, but my son wanted to jump in there and do it. He wouldn't have done that before.

Did attending the event increase the children's interest in a career in engineering?

39% of the families interviewed said that their child(ren) were already interested in a possible career in engineering before the event. Most of these families stated that the event had reinforced this interest. The following quotes are typical comments from families with children who were already interested in engineering careers.

Right now, she tells me if she doesn't get into Harvard or Yale, she wants to go to Marquette and study engineering.

I am pretty sure, he talks about it all of the time. It is something he likes. Participation in the event increased his interest…[now he knows] people actually get paid for it.

32% of the families interviewed said that their child(ren) were interested in a career in engineering and their interest was a direct result of attending the event. The following quotes are representative of this group of families.

Yes, a direct result. I think because it seemed accessible and because her friends were there and they were all kind of participating in this together and since we were there too, we could see what they were doing, but now I know her and her friends kind of have the same vocabulary with this engineering thing.

He was very excited about and it was obvious that he had a fun time and he said he wants to do more stuff like that.

From the families' perspective, attending the Family Engineering events made a positive impact on their family's knowledge of and interest in engineering. The events offered experiences that were accessible and fun, and helped increase families' understanding of the different types of engineering and what engineers do.

What are Family Engineering events like? 3 vignettes

In this section, we offer three different portrayals of Family Engineering events that took place in three separate regions of the country, and in different venues. We use pseudonyms throughout to protect the identity of the actual people and places. These portrayals, we believe, emphasize the diversity of

contexts and conditions under which these events are successful, and they highlight the flexibility and usability of the Family Engineering Book.[4]

Vignette 1

Jeff Samson, a career science educator, has been working with the Family Engineering group for over a year, piloting their curriculum at several schools in the Milwaukee area. He has developed a local program in collaboration with a local university to involve families in engineering. His group sponsored a Family Engineering event at Milwaukee Elementary a K-5 magnet school with high parent involvement. His goal for the event was for the families to leave with a "positive attitude about engineering and a better understanding that there are a lot of elements to it."

The event took place in a large, school cafeteria, a typical venue for Family Engineering events. The volunteers, engineering students from the local university, arrived early, before the event began, to help set up. A school dinner was in process when they arrived and a small group of parents and children were eating fried chicken, pizza, carrot sticks and cookies. Jeff and his team of volunteers–six female college students, all engineering majors--began to un-pack and organize the five stations on cafeteria tables. All of the stations had simple materials families can use to explore engineering principles in an engaging manner. There was the Engineer's Toolbox: a set of measuring tools such as measuring cups, a stop watch and a measuring tape and a collection of things to measure–spanning the possibilities from measuring a grain of rice to measuring the room. There was the Communication Station: two identical collections of Legos, one on each side. On one side a participant builds a small structure, out of sight of their partner. The builder then verbally leads their partner through building the structure and when they are finished they compare the two structures. There was the Thrill Seekers: a flexible tube with marbles that can take a journey from one end to the other (like a roller coaster). There was Glue is the Clue: glued and unglued stacks of index cards are set up to make bridges–the strength of the bridges are then compared using washers as weight. Finally, there was the Domino Diving Board: stacks of dominos are used to build an overhanging structure–the length of which is measured.

At 6:00 pm the families began to arrive in earnest and by the time the event was in full swing, there were about 70 people happily working together. The event began with stories from the engineering students about why they became engineers and descriptions of their work as engineers. The young women's stories were captivating and clear and the audience listened closely as they described a range of experiences from succeeding in upper-level mathematics and a desire to design artificial limbs. Inspired, the families fanned out amongst the stations where parents and children worked together to solve problems. At the Communication Station a father attempted to build a structure built and described by his young daughter. The mother watched and asked the daughter clarifying questions: is the red one on the right or the left? At the Rollercoaster marbles rolled backwards and forwards and all over the floor as a grandmother and her two young grandchildren twisted, raised and lowered the tubes. At the bridge station a tower of washers collapsed amidst laughter and groans from the family of builders. The Domino Diving Board was definitely the most popular station, perhaps because it involves some competition and anticipation. Who can make the longest cantilever, at what point will it collapse? At one point, a mother and her two boys had all six of their hands on

[4] All names of people and places used in these vignettes are pseudonyms.

the dominoes. One boy said to the other: 'counterweight, we need a counterweight!" Later, another family at this station, a mother and her daughter shrieked in amazement when they removed one domino and the entire structure collapsed. Families spent on average, 10-15 minutes at this station and were reluctant to move on, nonetheless, most of the families visited each station and spent more than 5 minutes at each one.

After about an hour, this portion of the evening wound up. Then Jeff spoke briefly about the ease of doing these activities at home with simple materials and urged the families to set aside some time to do so. The families helped to clean up and store the materials and then they all trooped out into the hall to play Agree or Disagree. The families lined up along each side of the hall, in two rows facing each other. The leader and volunteers read statements and if a family agreed with the statement, they stepped forward as a family. The leader read a range of statements designed to dispel common misconceptions about engineers–from 'Most Engineers build bridges and roads' to 'Men make better engineers than women.' There didn't seem to be any big surprises for the families–but it did give one of the students an opportunity to talk about how she was becoming an engineer in spite of many challenges and to encourage all of the children to pursue their dreams.

Next, the families moved back into the cafeteria to start on the final activity of the evening: the Launcher. Families were given the challenge of designing and building a launcher out of rubber bands, Popsicle sticks, tape and a plastic spoon. Each family had to draw a design before they could pick up the materials. A few families found it difficult to come up with a plan without trying something first, nonetheless, they all eventually drew simple plans and collected their materials. A launch pad was set up and the families competed to see who could launch a cotton ball the furthest. Families were allowed to test their launcher and then refine it and re-test it as many times as they needed. Again, all the families were engaged–even the one person who had not been engaged all evening got involved in the Launcher. This activity was more complex than those during the first part of the evening and more families needed assistance from the volunteers. The winning team–a Father and daughter–gave each other a high five when their cotton ball flew significantly further than the rest. The girl said triumphantly "That was MY plan!" A boy asked her–"How did you make it go so far?" She answered, "I made it nice and strong so it has lots of force!" Her Father asked, "Is there anything we can do to improve on it? Probably not," she answers confidently.

The evening wrapped up at the end of an hour and a half with a raffle–children went home with their launcher and memento of the evening. Surveys collected from families at the end of the evening (N=23) indicated that ninety-one percent (91%) of the families had enjoyed the event, felt that the activities had encouraged their family to work together and reported learning something new. Sixty percent (60%) of the families said they their ideas about engineers or engineering were different as a result of the event.

Vignette 2

Bromwell Elementary School serves a student population of about 750 students in a suburb of Washington DC. For the last year or so, spearheaded by Sherry, a teacher at the school, and a couple of other teachers, the school has been incorporating engineering lessons into every grade level. With the help of small grants, relationships with a local major research 1 university, and business partnerships, this group of teachers has slowly transformed the school so that it has a strong STEM focus, with a special emphasis in engineering.

In preparation for the first Family Engineering night at the school, Sherry talked about the level of commitment and extra time it takes to put on a family event, especially one like this one that is materials-intensive. She remarked:

> *I'm partnered with [another teacher] who is super excited about it, and that helps. Other teachers are also getting into it. Last night we stayed late putting things together, last week we worked until 8pm each night working on it. It is a passion… We are at the front of a wave. Obama mentioned [engineering education] in his state of the union speech. We want this for everyone—not just special populations.*

The school had a history of evening events for families, and Sherry felt confident that they could implement the engineering program, even though neither she nor any of her colleagues had training in the materials. They had hosted a family math event in the previous semester, where 500 families attended. For the Family Engineering night, she and her colleagues had recruited 15 or so staff (including their own principal, and a principal from another school in the district), and few parent volunteers–several of whom were engineers. In addition, she had 3 engineering undergraduate students from the local university (along with other volunteers and staff) to help facilitate some of the opener activities.

Since Sherry was expecting about 500 people, she organized the evening so that as families entered the school, they would be given a "passport" with an agenda for their evening, so that no one activity would be too overwhelmed with people. So, families either started in the cafeteria, where there were 10 of the "opener" activities set up at stations scattered throughout the room, or one of 5 other locations in the school where they would participate in one of 2 possible challenges: "Give Me a Hand" and "Blast-Off."

The night of the event, the entire school was set up to promote it, with flyers and signs everywhere about engineers and engineering. A large sign at the front office read: "Get Caught at Family Engineering Night!" As the volunteer engineering students arrived, one of the teachers coached them on how to facilitate the stations–primarily encouraging them to ask questions and not give answers. As families began to trickle in, students and other volunteers invited them to try their station.

Some families' passports directed them to an activity first. The "Give Me a Hand" activity challenges families to design and build a "prosthetic hand" using craft sticks, masking tape, rubber bands, paper clips, index cards, and a plastic spoon and fork. Constrained by these materials and only the use of a thumb and forefinger to operate it, their device should be able to pick up the test objects: cotton balls, erasers, pencils, marbles plastic cups, and paper. After a brief introduction to engineering, the engineer-facilitator of this activity invites families to imagine having no hands: "What would it be like to try and pick something up, button a button? How do people without hands pick things up? Well, biomedical engineers are trying to help solve that problem. Tonight, as a family, you will be an engineering team and create a prosthetic hand." He then described the materials and constraints, and to "use the steps that engineers use" to first talk, draw (design), then build and test their hands. Sitting around small round tables, families began by discussing ideas and drawing their concepts on paper. Parents urged their children to offer suggestions, asked them questions, and encouraged them to build their designs. During the workshop, families had time to iterate their designs as they tested them with the different objects.

In another space at the school, several groups of families were invited to build and test a bottle launcher in the activity "Blast Off." The challenge in this

activity is to build a launcher using a plastic bottle, straws, and masking tape, to shoot a rolled up piece of paper through the straw the farthest distance. Unlike the prosthetic hand workshop, this activity was ongoing, so as families entered the space, once there was a critical mass, the facilitator provided a short explanation and rationale for the activity, and let the families design, build, and test at their leisure.

By the end of the night, most all of the families (estimated to be over 400 total people) participated in both of the two longer activities, and spent time circulating through the shorter activity stations. After the families left and the clean up completed, teachers expressed that they were pleased with the turnout, and, based on what they observed and conversations they had with parents, they felt the event was a success. Surveys collected from families (N = 53) as they exited the event confirmed these feelings. All who completed the form said they would recommend the event to others, and agreed that the event encouraged their family to work together and that they learned something new. Seventy-two percent (72%) said that their ideas about engineers or engineering are different as a result of the event.

Vignette 3

In May of 2010, Inverness Research visited a Family Engineering field test site in Georgia. Prior to this particular evening's event (which was this site's fifth in total), the site hosted two Family Engineering events at a local informal science education institution (ISEI) and another three at three different elementary schools in the area. According to Emily, Susan, and Paula, it has become increasingly difficult to coordinate out-of-school programs, such as family nights, as opposed to in-school activities. In this case, the ISEI recruited the three schools (two public and one private) to host, through email that the Public Relations director at the ISEI sent through her network of schools and educators. A fourth event was held at a public school, following a PTA meeting there.

The evening's event would be held at Brooks Elementary School. Brooks stands on a small lot 25 minutes outside of a major city in Georgia. The school could be easily missed, as it doesn't look terribly different from a home or small business. As one drives further out of downtown toward Brooks Elementary, it is stunning how many small businesses and houses have been abandoned, sitting boarded and vacant.

When the Family Engineering project chose field test sites, they sought to establish a diverse set of sites—including formal and informal education sites, universities, libraries, and industry—as well as a diverse set of facilitators, including experienced and those new to the field. This facilitator, Emily, was described as the least experienced field test coordinator—one who also works for an organization that is relatively inexperienced with this model of family programming (even though they do provide hands-on science outreach programs). The project selected Emily and her ISEI precisely because the Family Engineering program is meant to work as a resource for others in just this scenario—without previous engineering expertise and new to planning this kind of family event (other field test sites have varied levels of expertise with this type of programming and are able to relate it to their experience with what works and what does not work).

Emily's background involved working part-time at the local ISEI, implementing outreach projects such as Family Engineering and one funded by the Army, involving classroom presentations and activities at local middle schools. She is a former classroom teacher and a mom who has been heavily involved in her children's schools and the community over the years. Having lived in the area

for decades, she is well-connected within the region. Regarding what is required of a facilitator to host a successful FE event, Emily said, "whoever it is has to have really good contacts with school systems. After-hours stuff is hard. Saturdays are easier than weeknights. It makes for a long night." Even so, Emily said, "The [Family Engineering] training was perfect. I was very overwhelmed and anxious but I jumped in there. Everyone is easy to work with."

As Emily and docents from the local ISEI (Susan and Paula) set up the event in the multi-purpose room at Brooks, the assistant principal, who helped to coordinate this event, arrives, along with the school's principal, the afterschool coordinator, and two teachers. Gradually, families begin to drift in. By 6:10 pm (the event was scheduled to begin at 6:00 pm) there are 16 "kids" of various ages (ranging from five years old to teenagers) and 10 adults. By 6:40, there will be 25 kids and 14 adults. Eventually, there will be 32 kids and 18 adults for a total of 50 participants, not including the many school staff and facilitators who are also present.

Emily begins with a whole group introduction, during which she talks about the purpose of the night (to test these activities and get honest feedback from families). She says: "all your criticisms and critiques are helpful. That's what we're here for." The first activity the group engages in is Engineering Charades, which is technically a short activity but Emily uses it as an icebreaker activity. It is a rousing game, through which families take one laminated card that names a particular kind an engineer and also has a picture of a tool that engineer uses or designs. The person whose turn it is tells the rest of the group what kind of engineer they are and then try to act out what the tool is, for the group to guess. It is a nice invitation into thinking about all the many different kinds of engineers.

The second activity families engage in as a whole group is one of two parts of "Bright Ideas," a 3-part challenge where families first explore a simple circuit, then reverse engineer a flashlight, and finally design a hands free reading lamp. In this case, Emily introduces the Engineering Cycle (Ask a Question, Plan, Create, Improve) and families are charged with trying to light up the light bulb with only a battery and wire. Then they engage in the hands-free reading light design challenge. It needed to be lightweight so it can be clipped to a book, tent, or person using materials such as pipe cleaners and masking tape. They continue with another design challenge, which is to build the tallest tower possible out of pipe-cleaners. Following each of these activities Emily asks families (adults and kids) to complete an evaluation form that rates various aspects of the activity. As a thank you gift, Emily gives each family passes to the ISEI and holds a raffle for prizes such as glow in the dark bracelets, balls, kites, power shooters, water blasters, and Jenga.

This event was a nice example of how an ISEI can work with and support schools, to increase attendance at family engineering events. The facilitator at this particular event is also representative of the intended audience of the Family Engineering project. The event we observed was well-organized and all the families took time and care to fill out all the evaluation instruments regarding the activities they participated in.

Each of these vignettes describes a different approach to the facilitation of a Family Engineering event to accommodate the venue, the participants, and the goals of the people orchestrating it. In each case, families were able to participate in multiple experiences—some of them quite short and others long

and involved, where each step of the design process was explored. Facilitation provided enough information for families to feel comfortable and to support them in designing and exploring together; the combination of support and good materials contributed to mostly positive experiences for families. Organization is key: event organizers who can anticipate the questions and issues that families will experience provide a more seamless experience from the families' point of view.

Results from exit surveys and interviews suggest that these families benefited greatly from the events and would support future events. These vignettes, along with the interview and survey data, and the extensive evaluation of the pilot events, strongly suggest that the guidebook provides the background and implementation information to enable successful orchestration of engineering experiences for families.

The Broader Impact of Family Engineering

From our assessment of the Family Engineering program so far, it is safe to state that the events can have a highly positive and lasting impact on families and their children. Potential and actual facilitators of events find the guidebook to be excellent along many dimensions. The venue in which a Family Engineering event is held does not seem to matter, as long as there is ample space for participants, and enough volunteers and staff to facilitate the activities that are chosen.

Our research was not able to uncover the extent to which different levels of support for facilitators, such as professional development experience, make a difference in the quality of the event. Based on our feedback from families who attended events that were facilitated by trained and untrained facilitators, there does not appear to be much of a difference.

Training opportunities for staff and volunteers was something many of our informants said would be useful. Although they did admit that the book was self-contained and had most everything they needed to create and orchestrate a successful event, a few noted that a workshop, or experiences with people more familiar with the guidebook, with tips for use, would be something they would be interested in, and willing to pay for. Several of the interviewees we spoke with noted that in addition to having more than adequate background information, there are also plenty of activities to work within the guidebook. A few interviewees stated that they could easily host at least six to eight different events, based on the activities in the book.

As with Family Science and Family Math, these events are typically "one off" experiences for families, with little or no follow up. Based on some anecdotal evidence, as well as the overwhelming positive ratings from families who attended and would recommend the event to others, we believe it would be useful to support organizations to offer an ongoing series of events—this could go far in building relationships among schools, families, children, and the discipline of engineering.

Further, we believe Family Engineering can make a timely contribution to the broader push for engineering education. Next Generation Science Standards, scheduled for release in 2013, will emphasize the importance of science *and* engineering practices and schools will be seeking resources to help them introduce engineering to K-12 students and their families. Change in the K-12 system is slow, and while engineering programs are gaining ground, it may take years for engineering education programs to become commonplace. A Family program like Family Engineering is a "low hanging fruit" for bringing engineering into communities. These events are low-stakes opportunities for educators and families to explore engineering together, and strengthen relationships within the community.

Finally, the Family Engineering leaders have already begun dissemination efforts that we believe can produce a roster of Family Engineering champions

across the country ready to host Family Engineering events in their communities. With more extensive training, currently provided by one or more of the program developers, many of these individuals may also be tapped for ongoing efforts to disseminate and train new users of the program locally and regionally. Drawing upon already established networks of informal science education institutions, ASEE, professional engineering societies, and other organizations, a strong organically grown network of engineering education advocates and Family Engineering users can be built over time. This network can host local events, facilitate local trainings, and help the project team continually identify novel and successful approaches for volunteer recruitment, program implementation, and capacity building for Family Engineering nationally and internationally. Further investment in these dissemination efforts will facilitate broader implementation of Family Engineering as a valuable resource for families, schools and communities working to strengthen STEM education locally. Family Engineering can also become, over time, a valuable resource for public and private entities dedicated to cultivating a more competitive and innovative 21st Century workforce.

References

Coates, G. (2011). Personal Communication.

Ferguson, C., *et. al.,* (2008). *The School Family Connection-Looking at the Larger Picture* National Center for Family and Community Connections with Schools

Henderson, A. and N. Berla. (1994). *A New Generation of Evidence: The Family Is Critical to Student Achievement.* Washington: Center for Law and Education. ED375968.

Henderson, A. and K. Mapp. (2002). *A New Wave of Evidence: The Impact of School, Family, and Community Connections on Student Achievement.* National Center for Family & Community Connections with Schools.

Katelin, L., Pearson, G., Feder, M. (Eds). (2009) Engineering Education: Understanding the Status and Improving the Prospects. Committee on K-12 Engineering Education, NAE and NRC.

Weiss, Caspe, and Lopez. (2006). *Family Involvement in Early Childhood Education.* Harvard Family Research Project.

Appendix A

Inverness Research was hired in the late spring of 2010 to take over the summative evaluation. By the time we were on board, the majority of the field testing had been completed. David Heil and Associates conducted the formative evaluation, and produced an extensive and detailed report on the findings from the field tests and expert engineer and educator reviews of the activities.

Our approach and data collection methods included the following:

- Site visit to one field test site and event
- 28 telephone interviews with families who attended any field test events
- 3 event observations in the winter of 2010-2011, arranged by project leaders
  - interviews with event leaders (N=4)
  - exit surveys for families/families at the events (N=87)
- Telephone interviews with 6 people who purchased the final version of the Family Engineering book
- Survey of people who purchased the final version of the Family Engineering book (we sent emails to 89 people inviting them to fill out a 10-minute online survey, 28 responded for a response rate of 31%)
- Extensive interviews with PIs and key advisors

In addition, we drew on findings and instruments from the formative evaluation work conducted by DHA.