

Family Engineering for Elementary-Aged Children and Their Parents

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Abstract

The goal of the Family Engineering program is to engage, inspire, and encourage elementary students to learn about and consider careers in engineering and science through hands-on activities with their parents at Family Engineering events. This program is designed to address the United States' need for an increased number, and greater diversity, of students skilled in math, science, technology, and engineering. The Family Engineering program for 6-12 year-olds and their parents is modeled after the popular *Family Science* and *Family Math* programs. Family Engineering increases public understanding and appreciation of the role engineering plays in everyday life and encourages parents and children to consider engineering as a career. Student chapters of professional engineering organizations on college campuses, elementary classroom teachers, engineering professionals, and informal educators at museums are likely to want to host Family Engineering events.

A set of family engineering activities representing typical engineering disciplines and concepts has been developed and field-tested to determine its suitability to a wide range of settings and audiences. The family engineering activities were assessed at 8 sites (in California, Connecticut, Georgia, Michigan, Mississippi, Puerto Rico, Utah, and Wisconsin) during spring 2010 with positive results. Activities fall into three categories – icebreakers, short or opener activities, and longer engineering challenges. The opener activities are set up in advance and are self-paced so families can work on them as they arrive at an event. Icebreakers draw attention from the short activities, bring the participants together, and set the tone for the rest of the event. The engineering challenges engage families in the engineering design process. Participants are challenged with an engineering problem such as designing a thing or a process. They ask about the challenge, imagine various solutions, plan a specific solution, create the thing or process, and then improve on their designs. Field test activities and events were evaluated by event participants, facilitators, and experts in education and engineering. The results have shown that most of the activities that were developed are fun and engaging and that children and their parents experienced significant increases in their interest in and awareness of engineering in their everyday lives as a result of the program. Parents also reported an increase in their willingness to consider engineering as a possible career option for their children.

Introduction

The demand for scientists and engineers is growing steadily, but the US is unable to meet that demand. The resulting shortage of technically skilled employees threatens national economic and technological competitiveness. Often pre-college students

have not been introduced to science, technology, engineering, and math (STEM) in a way to attract them to the fields as a career. This has been particularly challenging for the engineering field, since specific instruction in engineering is quite limited in K-12 settings, with most engineering offerings not appearing until the high school years. In an effort to increase awareness, programs such as “Engineering is Elementary” and “Project Lead the Way” have developed curricula that can be used in school settings, and programs such as FIRST have been developed to pique interest in engineering and science through competition. But, none of these programs actively engage parents and children in exploring engineering together.

Parents play an important role in developing their children’s career interests by providing support, guidance, career and educational suggestions, and life experiences that support career development¹. Therefore, a child’s elementary years are an ideal time for engaging parents in informal science and engineering education programs. Because parental influence plays a key role in children’s educational achievements, parent/family involvement is an essential part of the solution to the looming STEM crisis. Studies have found that student achievement increased directly with parental engagement². When parents participate in their children’s education, students’ achievement and attitudes improve³. Other benefits include higher aspirations for school and career development⁴. Over the past two decades two programs have demonstrated the power of parent/child learning in science and mathematics. These programs with their respective publications, *Family Science*⁵, and *Family Math*⁶, have offered teacher/parent trainings and hosted events for families in communities across America and around the globe, successfully engaging families with elementary age youth in hands-on science activities and problem solving. By introducing science and math concepts early, these programs are helping to increase parents’ and children’s interest and confidence in doing science and math, as well as providing parents with resources for encouraging their children to study science and math in school and consider possible careers in these fields. These two programs have been particularly successful at reaching out to families traditionally underserved in science and math, including families from inner urban, rural, and minority communities. Both programs offer publications and program delivery in both English and Spanish to assist in reaching diverse audiences.

In its report *Changing the Conversation*⁷, the National Academy of Engineering concluded the public image of engineering needed to reflect the optimism and aspirations of students and needed to be inclusive. Some of the misconceptions included 1) engineering work is a sedentary desk job, 2) engineering is strongly linked to math and science, but not to other vital aspects, such as creativity, teamwork, and communication, and 3) engineers are not seen as directly helping people. NAE observed that many kids want a well-paying job that makes a difference – something that can easily be linked to engineering.

Family Engineering is being developed to provide a vehicle to promote early interest in, and a better understanding of engineering through the use of fun, hands-on activities designed to present basic engineering concepts and skills to families with elementary age children. By actively engaging families in these activities, the

program is helping to lay a foundation for future learning in STEM related fields and for increased parental confidence and comfort with encouraging their children to study STEM topics in school and consider a possible career in engineering. Initial program research and development is being supported through a grant from the National Science Foundation. The purpose of this paper is to briefly summarize some of the features of the Program.

Goals of the Family Engineering Program

The goals of Family Engineering are 1) to engage families in engineering with fun, hands-on activities, 2) to increase public understanding and appreciation of the role engineering plays in everyday life, 3) to introduce children at an early age to the many career opportunities in engineering, 4) to increase parents' interest in and ability to encourage their children to pursue an engineering career, and 5) to provide age-appropriate resources to support volunteers in conducting informal engineering education programs with elementary-aged children and their parents. These goals are accomplished by conducting events in informal community settings.

In the development phase of the Family Engineering Program, consideration was given to what families need to know about engineering. The project team developed the following list:

- Engineering is the use of imagination, along with science and math knowledge, skills, and experience, to address challenges and design solutions.
- Science, math, technology, and communication are important tools for engineers
- Engineers are creative problem-solvers
- Engineers improve people's lives and make the world better
- Engineers help shape the future
- Engineering problems usually have multiple solutions
- Engineers are from all races, ethnicities, and genders
- There are many different fields of engineering
- There are many great career opportunities in engineering

Family Engineering Program Components

As mentioned above, the Family Engineering program is being modeled after two previously developed and successful programs – Family Science and Family Math. Key program components include the following:

- Publication of a book of hands-on activities titled *Family Engineering: An Activity and Event Planning Guide*, with both English and Spanish language editions. Included in the book are suggestions for how to foster engineering learning in the home and other informal, non-school settings, as well as how to reinforce the importance of science and math course work in school. In addition, the publication provides information and resources for hosting Family Engineering events in school and community settings.

- A variety of tested event formats for implementation by volunteers trained to facilitate and host Family Engineering events in their community. These formats are described in more detail later in this article.
- Professional training opportunities for educators, engineers, and STEM undergraduate students interested in volunteering to help host and/or facilitate Family Engineering events and activities in their community.
- An interactive website with additional resources and materials to support families, trained volunteers, and others interested in implementing Family Engineering in their community.

Development of Family Engineering Activities

A number of dimensions were considered in designing successful activities for Family Engineering. Based on the development team's prior experiences with Family Science and research on teaching and learning in informal settings, the following were identified as important characteristics of a Family Engineering activity:

- *Encourages Family Interaction*: the approach, activity design, and materials invite and encourage parents and caregivers to work and learn together with their elementary-aged children.
- *Fun and Engaging*: activities are informal, enjoyable, and maintain the interest of participants; spark a desire to continue learning about engineering; create positive associations with engineering; create feelings of confidence and ability with relation to engineering
- *Original Material*: activities should provide a new and novel way of exploring engineering concepts; avoid activities that have already been published or are common practice in the informal science, engineering, or enrichment education field.
- *Inherent Engineering Connection*: a connection to engineering content and/or engineering careers is obvious and built in to the context and facilitation of the activity.
- *Approachable and Accessible*: activities require no specialized knowledge of engineering to participate or facilitate; activities are designed so that participants and facilitators feel confident and capable in completing them; activities are appropriate for and inviting to diverse audiences (socially, ethnically, economically, geographically, academically, and culturally).
- *Relevant to Elementary-Aged Children and Their Parents*: activities deal with challenges and subject matter that are relevant, interesting and meaningful to children in grades 1-5 and their parents.
- *Promotes Problem-Solving*: activities encourage finding multiple solutions through inquiry, testing, and teamwork.

- *Simple, Inexpensive Materials*: materials should be easy to acquire, simple to use, and able to be gathered in large quantities for events without a large expense.
- *Safe*: materials and methods for an activity must provide for safe engagement at home or within the open structure of an informal public event. In particular, short activities need to be safe and functional without any facilitation or supervision.
- *Written for Facilitator*: the primary audience for Family Engineering activities is the individual who will be planning and implementing Family Engineering events for elementary-aged children and their families. Parents may also be facilitators at schools, home, or community settings.
- *Suitable for a Variety of Settings*: schools, community centers, churches, homes, museums, etc.

In addition to having the above features, there are a number of engineering concepts and skills that are introduced and reinforced. This list includes:

- *Engineering design process*: A series of steps that engineers use to guide their problem-solving. Family Engineering has adopted a simple 5-step version of the design process used by the Engineering is Elementary (EiE)⁸ curriculum - Ask, Imagine, Plan, Create, Improve.
- *Teamwork*: the ability to function on multidisciplinary teams.
- *Open-ended problem-solving*: the ability to identify, formulate, and solve problems.
- *Communication*: the ability to communicate effectively with others.
- *Societal and environmental impact*: the ability to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
- *Design under constraints*: the ability to design a component, product, or system to meet a desired outcome or solution while accommodating a range of constraints. Constraints may be economic, environmental, social, political, ethical, health and safety, manufacturability, materials, or sustainability-related.
- *Controlled experimentation and testing*: the ability to design and conduct experiments, as well as analyze and interpret data. Understanding of what constitutes a “fair” test.
- *Role of failure*: the recognition that failure plays an important role in the design process and is not necessarily a negative outcome; learning to use failure to find a better solution.
- *Reverse engineering*: the deconstructing, or taking apart, of a product or process to figure out how it works.
- *Systems*: the ability to design systems, where many processes must work together.

- *Optimization/trade-offs*: the ability to make trade-offs, or optimize a process, in order to enhance its benefit and minimize negative impacts.
- *Spatial visualization*: the ability to envision 3-D models from 2-D drawings and to “see” how things fit together.
- *Modeling*: the recognition that designs can often be optimized by building models and/or by constructing and testing prototypes prior to building a final product.
- *Properties of materials*: the ability to select the proper material for a given product; recognizing that the properties of a material will determine how that material contributes to a solution.

Forty family engineering activities have been developed. These activities fall into three categories: 1) short, self-directed activities 2) icebreakers, 3) longer, facilitated engineering challenges. Table 1 gives examples of the short activities and the engineering challenges. The short activities have been designed to set up before an event so that families can begin working on them as they arrive at an event location. A short activity will typically take one to five minutes to complete. It encourages quick parent/child engagement, and no supervision or facilitation is required. An easy-to-read sign is placed next to the activity materials, and families work through a simple, hands-on activity that introduces only one or two engineering concepts. Materials are easy to reset or replenish for the next family. The signs also include a short engineering connection explaining the basic engineering concept represented.

Table 1. Examples of Family Engineering Activities.

Name of Activity	Engineering Hook	Engineering Field(s)	Type of Activity
Opener Activities			
Diving Board Dominoes	How far out can you build a cantilever?	Civil Engineering, Mechanical Engineering	Hands-on building
Inspired By Nature	What human inventions have been inspired by natural objects?	General Engineering	Card matching
Solid Ground	What granular material makes the best base?	Geological Engineering	Hands-on testing
Thrill Seekers	Build a roller coaster with turns and loops.	Mechanical Engineering	Hands-on building and testing
Engineering Challenges			
Assembly Line	Design an assembly process to minimize time of assembly	Industrial Engineering, Manufacturing Engineering	Hands-on design

Blast Off	Design and test an air-launched rocket made from specified materials	Aerospace Engineering	Hands-on design and testing
Give Me a Hand	Design a mechanical device to pick up a selection of different objects	Biomedical Engineering, Mechanical Engineering	Hands-on design and testing

An icebreaker activity is used to quickly focus family participants' attention and allow the facilitator to welcome the group and provide an overview of the event. The icebreakers typically introduce families to engineering as a profession and highlight common misconceptions about the field. They can also be used at the end of an event to help bring closure.

Longer, facilitated activities are designed to engage families in more in-depth problem solving and hands-on engineering challenges. They typically take 20-40 minutes to complete and emphasize parent/child interaction and active engagement. Instructions for facilitators include descriptions of recommended discussion questions, materials distribution strategies, and group facilitation techniques. They may also include extensions for when additional time is available or take-home ideas to encourage continued family learning and exploration. They include necessary hand-outs or activity sheets, and include a cultural connection and/or fascinating facts about the concept or engineering field featured in the activity.

Family Engineering Events

The *Family Engineering* publication serves as a resource for individuals or organizations wanting to provide informal engineering education opportunities to elementary-aged children and their families through fun and engaging community events. In addition to a collection of hands-on engineering activities, the book provides all the tools necessary to plan, organize and implement a successful Family Engineering event. A number of specific target audiences have been identified as potential event facilitators and users of this resource – professional engineers and engineering societies, student chapters of engineering societies, informal educators, formal K-5 teachers, and parents.

The Family Engineering Program has developed a variety of successful, proven event models for implementing a Family Engineering event. A typical Family Engineering event will last from 1½ - 2 hours as shown in Table 2 and begins with a variety of short activities – engaging experiences set up as table-top stations – available for families to explore at their own pace as all participants are arriving. After enjoying the short activities on their own, families are gathered together as a large group to be welcomed and oriented to the next part of the event. At this time, an icebreaker activity can be used to loosen up the group and get families thinking

about engineering and how it impacts their everyday lives. Following these shorter “openers” and “icebreakers” event facilitators introduce families to longer activities that allow them to more deeply explore an engineering concept or discipline or experience the engineering design process first hand.

The longer, facilitated activities may last from 20-40 minutes each and allow families to work together to solve an engineering challenge or explore an engineering topic in more

Table 2. Typical Family Engineering Event Schedule.

Time	Event Activity
2 hours before event start time	Arrive at venue and set up event
30 minutes before start	Brief event volunteers
Event start time	Families arrive and begin working on opener activities at their own pace
30 minutes after start time	Families brought together to be welcomed to the event and learn about engineering
40 minutes after start time	Families work on engineering challenge activities
100 minutes after start time	Wrap up the event
110 minutes after start time	Clean up (takes about 30 minutes)

depth. This portion of the Family Engineering event can be implemented in a variety of formats. Two different formats that have been developed and field-tested include:

- A facilitator leads the entire group, working in family teams, through 2-3 facilitated activities. Other staff/volunteers assist with distributing materials and helping families engage in activities.
- Participants split into smaller groups, with participants remaining in their family units, to participate in 2-3 facilitated activities conducted in separate rooms with two or more activities occurring simultaneously. Families rotate through 2-3 different activities during this event format.

Following the longer activities, event participants can be brought back together as a group to share some of their learning outcomes and new perspectives on engineering, and be made aware of the *Family Engineering* publication, website and other Family Engineering related resources available to support their further exploration of engineering. If appropriate, take-home materials can be provided to encourage families to continue exploring and learning together.

A Family Engineering event can also be a wonderful opportunity for participants to meet and interact with professional engineers or engineering students. If any of the facilitators and/or volunteers for an event is a professional engineer or engineering student, some time may be dedicated to introducing them to the group and having them answer career related questions from the audience or facilitate a Family Engineering activity that focuses on engineering careers.

Evaluation and Expert Review

The activities and event formats were recently tested (spring 2010) at select locations in California, Utah, Michigan, Wisconsin, Mississippi, Georgia, Connecticut, and Puerto Rico.

Each site hosted a minimum of five events presented to a broad range of audiences representing different community locations, socio-economic levels, ethnic backgrounds, and facilitation models. Field Test Coordinators have also come from diverse backgrounds in order for the project team to test viability of various volunteer demographics and backgrounds. During the Field Test period from February through May of 2010, Family Engineering events and activities were facilitated by engineering university faculty, undergraduate students enrolled in STEM programs, teachers, professional engineers, informal educators, and some parent volunteers. Events have been held in elementary schools, science centers, community centers, and corporate settings in order to test a range of locations and facilitation formats and delivery.

At each of the field test events, evaluative feedback was gathered from participating families, volunteer facilitators, and site coordinators. For example, Table 3 summarizes average responses of all of the families during field testing to several questions assessing the impact of the events. They show that families significantly increased their interest in and awareness of engineering, and that they would consider encouraging their children to consider engineering as a career. Other results from this formative evaluation were used to guide final development of the activities published in the *Family Engineering* guidebook.

Table 3. Impact of Family Engineering Event during Field Testing.

	Before attending Family Engineering we were	After attending Family Engineering we were ...
Interested in engineering.	3.52	4.53*
Considering engineering as a possible career option for our child/children.	3.45	4.33*
Aware of the connections between engineering and everyday experiences.	3.45	4.59*
Aware of what engineers do.	3.53	4.67*

**Change in mean is significant based on a paired sample t-test, p-value <0.05.
Average Rating based on a scale from 1 (strongly disagree) to 5 (strongly agree).*

During the field test phase, a cadre of professional engineers, engineering educators, and experienced formal and informal educators were identified to conduct expert reviews of the draft Family Engineering materials. This review, facilitated by the formative evaluation team, provided expert opinion on the engineering content and educational pedagogy reflected in the activities being developed. The reviewers' comments helped inform the refinement of the Family Engineering program.

Summary

A program has been developed that includes publication of an activities and event planning guidebook, development of a web site, and provision of training for facilitators. The activities and event formats were extensively tested under a range of settings and with a range of audiences. It was determined that Family Engineering events significantly increased a family's interest in engineering and engineering careers.

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