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Empty Choice: Can Girls "Want" Engineering If They Don't Know What It Is?

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Introduction

In mid-2008 a flurry of reports in the mainstream media suggested that girls and women in the U.S. today are purposefully choosing not to pursue STEM fields (McArdle, 2008; Sax, 2008; Sommers, 2008; Tierney, 2008). The argument made in these reports was: Today, girls and women know about STEM fields, and they know what to expect of STEM careers; on the basis of this knowledge they decide they are not interested, and they choose other fields. McArdle, writing in the *Boston Globe*: "When it comes to math- and science-related jobs, substantial numbers of women—highly qualified for the work—stay out…because they would simply rather do something else." She goes on to call this "a natural artifact of a free society." Sax in *Education Week*, "The real gender gap is not in…what girls and boys can do, but in what girls and boys want to do…." And Sommers in *Teachers College Record*: "…men and women differ systematically in their interests and …these differences can account for a large share of the gender gap in information technology occupations." Commenting on the same study as Sommers, Tierney in the *New York Times:* "…the researchers found that information technology workers especially enjoyed manipulating objects and machines, whereas workers in other occupations preferred dealing with people… There just happened to be more women than men with those preferences."

The idea that informed women are choosing against STEM fields, coupled with the fact that the percentages of women in fields like engineering have not changed very much despite years of support programs, have led some to assert that policy initiatives and programs that support or protect women's STEM participation (Title IX, NSF targeted programs for women and minorities) should end. These programs are said to be wasteful of scarce federal dollars that could be better spent on Mars Rovers or supercolliders. They are said to "infantilize" women by trying to change their perspective, alter their interest, and manage their career choice.

Results from the program intervention and research study that we have been conducting for the past 3 years challenge this view of the situation and suggest the need for more, and perhaps different, but not fewer, targeted efforts to encourage girls' and women's participation in STEM. Our results are consistent with Dorothy Holland and her colleagues' (Holland, Lachicotte, Skinner, and Cain,1998) work offering a different theoretical perspective on these issues. They argue that interest develops as individuals participate in communities of practice, as part of their sociocultural practice. Sites get their shape and characteristics from two primary processes: (1) the historical legacy of

social organization and institutional life in the society; and (2) the "figured worlds" (cultural imaginaries, intentional worlds) that provide a horizon of meaning for what takes place in the site. Individuals develop predispositions for participation in sites of social practices from a personal history of being positioned by others and responding to those positionings (Gullestad, 2003; Holland and Lachicotte, 2007). They find opportunities to develop their predispositions or not depending on the sites of social practices to which they have or can gain access.

As opportunities to participate in sites of practice change over time (through history, across contexts, as one matures, or from individual action), interest will be affected. Interests valued in one site may have no place or a quite different place in a second site; interests promoted in one site may be discouraged or ignored in another. Of course, individuals' interest developed in one site can be carried to another, but they may or may not be relevant there, and it may or may not be possible to develop them there. In other words, sites of practice embed expectations for interest that individuals who participate in the site must answer. Sustained experience in a site of practice increases individuals' interest along the lines emphasized in the site.

If new sites of practice are encountered, individuals will be challenged to fit prior interests, sense of self and identity into the grooves offered by the site, develop new ones that will "work" in the site, or decide not to participate in the site. This theoretical perspective makes interest more malleable and heavily dependent on contexts of practice to encourage interest, regardless of age, gender, or other demographic characteristics..

Our argument is that the figured worlds and social organizational forms of schooling and family life in the U.S. today contain almost no impetus—no sites of practice--for most girls to develop interests related to engineering. Most girls know little or nothing about engineering or the kinds of things that engineering involves, and thus, they have no way to develop an interest in it. Yet, if high school girls can be nurtured in rewarding opportunities to explore and experience engineering, many more girls may become interested and want to pursue it.

The Study: Female Recruits Explore Engineering (FREE)

In Summer 2006, researchers from the University of Colorado-Boulder, Iowa State University and Ohio State University began work on a collaborative research and intervention project, Female Recruits Explore Engineering (FREE), supported by the National Science Foundation. The 10-person research team has expertise in educational research, engineering, women's studies, sociology, higher education, computer science, and bilingual education.

In Fall 2006, the team identified 131 10^{th} grade girls with strong academic records in mathematics and science at 7 high schools in 3 states (Colorado, Iowa, and Ohio) and invited them to participate in an after-school program to explore career possibilities in engineering; the girls included Latinas, African-Americans, Native Americans, and a few Whites; many of the girls live in families that qualify for free or reduced lunch at school;

few had considered engineering as a college or career choice. Since 2006, we have met monthly with these girls to explore engineering, meet practicing engineers, visit engineering workplaces, discuss the pros and cons of engineering, and conduct hands-on engineering, all in an effort to increase the girls' knowledge of and interest in engineering. We developed a secure website for the girls to share their explorations, and we gave each girl a Blackberry smartphone to communicate with other FREE participants and the researchers. In fall 2008, we began case studies with 24 from the original group of 120, and we have continued to offer support and advice to all the girls during 2008-2009. In May, 2009, the girls will graduate from high school. With data from this intervention, we are addressing the following research questions: What is important for young women (high school girls) to know about engineering and how do they find out about it? How does the prospect of a career in engineering fit into the social contexts of the girls' lives? How do the girls' racial, socio-economic, and rural/urban locations influence their perspectives on engineering? And, how and why do young women's interests in engineering change over time?

We used multiple methods of data collection: participant observation to record what happened during the monthly meetings; interview-type questions posted on the website about the girls' developing ideas of engineering; surveys about the girls' previous experiences with engineering and technologies, school performance, future plans, and social networks. We captured girls' website postings and electronic messages from their Blackberries.

Fieldnotes, interview responses, website postings, and Blackberry messages were analyzed using a coding scheme developed from the research questions (a priori codes) and a preliminary review of 2 months of the accumulated data from each of the 3 states (in situ codes). The coding scheme was applied to the data in ATLAS.ti, a software program for qualitative data. The data were coded by: girls' interests, knowledge of engineering, knowledge of information technology, use of engineering (or IT) language, position-taking viz. engineering, constructions of engineering as gendered, future plans, fit with lives, and representations of ethnic, class, gender, age, or rural/urban location. These coded categories were also sorted into 2-month segments from Nov 06 to Jul 08 to capture changes over time.

The website and Blackberry data (>100,000 messages) required special treatment. To handle these data, E-Data Viewer was created by one of the researchers to process the messages in their original e-format, thread them together into conversations, and store them in a database. Incorporating color, size, and vertical sorting, the application creates visual displays of the data. Researchers can view individual messages in a separate window. They can trace individual threads to read conversations in their natural order. They can code and import text and codes to WORD and then ATLAS.

The surveys were analyzed for frequencies and compared to similar samples in other studies.

<u>The First Months of FREE</u>

Our first important discovery was that most of the girls knew little about engineering when FREE began. Engineering was not so much unappealing or uninteresting as it was unknown. 36% of CO girls, 10% of OH girls, and 30% of IA girls knew an engineer when FREE began. 23% of CO girls, 27% of OH girls, and 30% of IA girls were considering engineering as a career option.

One of the first activities we offered the girls was a trip to a Career Fair where they met and interacted briefly with representatives of engineering companies and schools. Prior to the trip, we asked the girls to suggest questions they would like to ask the Career Fair representatives. The questions they generated were offered tentatively and focused on very basic aspects of engineering (of any job, really). Some typical questions were:

What do engineers do?[1]
What types of engineering are there?
What do you like about engineering?
What do engineers make [as a salary]?

We selected a small subset of the girls' questions to serve as a protocol for their talks with the representatives. Once at the Career Fair, most of the girls stuck closely to the protocol, and once finished with the list or after receiving an unexpected answer, they had trouble generating additional questions to follow up.

After the Fair, it was still clear that their knowledge was thin.

Stephie: I was told what chemical and mechanical engineering is, however, I can not recall what they are. I learned that there are different kinds of engineering, like aerospace and more. I also learned that in some cases you do not need a lot of background in science and math but other times you need to know a lot in math and science… I would like to know more about the other kinds of engineering and what they do. Also, what kind of profession do engineers can get in to?

Jayde: I would like to learn more about the types of engineering, and how they affect the lives of people.

Lizbeth: I had absolutely no idea of some of the engineering things there was. I felt concerned that I probably had to know more than I did, but at the end of the day I had somewhat of an idea of the kinds of things that go on into the field of engineering.

After the career fairs and several FREE meetings where types of engineering were highlighted (videoclips of young women working at Google, Engineers without Borders, and women of color in a variety of engineering roles; a hands-on activity to make a heart valve; a demonstration of how to make a prosthetic device), the girls' knowledge grew. They began to name more kinds of engineering, identify more characteristics, and express more personal interest.

[1] Text color indicates school of speaker.

Stacy: I learned that engineering requires dedication, commitment and hard work. I also learned that there are several types of engineering such as: Chemical, Mechanical, Electrical, Civic engineering and many more.

Liz: I would like to learn more about biochemistry engineering… . I would also like to learn more about medical engineering. I think I would like to learn more about Aerospace engineering and the medical side of engineering as well because I found them to be interesting and I didn't know much about them.

Angel: I would like to learn more about the engineering that had to do with working with technology and creating like shirts with lights and all that other stuff… . I would also like to learn more about the engineering department that worked with the measurements of earthquakes.

Mikey: I would like to learn more about mechanical engineering. I also want to know if there is any field in engineering that deals with the medical field.

Ayan: I would like to learn more about chemical and civil engineering.

Loni: I would like to learn about civil engineering more, and also engineering that works with computers, and computer building and design.

Stephie: I would like to know more about aerospace engineering and engineering that builds the pieces for larger components like aircraft.

Sophia: I would like to learn more about medicine, forensics, and maybe civil engineering. I have been interested in medicine and forensics for a while, but I never thought about civil engineering until the career fair. I find it interesting and I would like to know more about what it involves.

They expressed surprise and wonder at the variety and range of engineering activities.

Loni: I learned that engineering is a great type of career that can help you achieve a lot in life, and that there are all different types of engineering so you can work on one type that you are good at, or one that attracts you.

Sophie: One thing that impressed me was that there are so many different people working as engineers with such different personalities, that it showed that no matter what kind of person you are or what your interests are you can become an engineer. Another thing that surprised me was that mostly every person we interviewed said his or her job was fun and that they had a lot of freedom… Some things I didn't know about engineering before the career fair was that there are so many different types of engineering. There are so many branches of engineering that basically for anything you want to do you can be an engineer, even if it isn't directly connected to engineering. Like one of the girls we talked

to said she was kind of an engineering lawyer which I thought was kind of crazy because I didn't even know that profession existed.

Stephie: There are a variety of things that impressed me in a positive way. One was that it made me even more interested in engineering. It made me think what I can accomplish with my life choosing engineering and many other things. Also, another thing that impressed me is the different choices in career jobs and the different professions you can choose from.

Liz: I didn't know that engineering was such a broad subject!

They were pleasantly surprised by the amount of teamwork involved in engineering.

Lizbeth: What I learned that I didn't know before was that every different kind of engineering helps each other out. For example, with aerospace engineering, the projects they made they needed help from the other kinds of engineering.

Angel: What impressed me the most is how the people that worked in the car and with the earthquakes…were all very cooperative. They all worked together and helped each other learn new things.

Ayan: The fact that engineers work as a team impressed me because before I assumed it was a more independent job instead.

Loni: I learned that every engineer has their own responsibility in a project. The way that every engineer worries about a different part of a project to make everything work smoothly.

They were especially impressed with how much engineering can affect people's lives.

Jayde: I got a chance to see other fields of work. I had no idea how much engineering affects our everyday life… I learned that engineering can really make peoples everyday life so much easier, and I really want to change people's lives in a positive way.

Mirele: I learned that the people in different fields have fun and have something to offer society.

They began to think about how they could pursue pre-existing (non-engineering) interests in some kind of engineering field. Loni wanted to know whether there is any connection between psychology and engineering. Others asked about forms of health, forensics, and medical engineering because they were already interested in those areas.

At the same time, however, concerns about engineering also began to surface. One concern was about how much math and science might be needed.

Loni: I learned that math and science play huge roles in an engineer's life.

Stacy: The main concern I had was just that I don't feel like I'm educationally ready in math to be a engineer.

Remy: I am more interest, but I'm also kind of nervous because I know that engineering requires a good math background. I am not bad at math, but I struggle with problem solving which is an important skill in real life application.

Mya: The fact that most engineers have to take quite a bit of physics and be in high math bothered me. I don't like physics and I am already in high math and it's not too easy.

Mina: I am concerned about the science I would have to take to be an engineer.

Another concern was how demanding the job can be. Girls worried about long hours, lots of responsibility, lots of stress, and balancing work and family.

Ayan: The commitment and responsibility being an engineer requires concerns me. Every person has their part and it has to be done correctly and on time. The stress this career is capable of causing seems like it may be overwhelming.

Jayde: I learned that most engineers work 10-12 hours a day, when I grow up I want to spend a lot of time with my family, if I work that much I would not have much time to do that.

Loni: I was concerned the most when learning that engineers had to take a lot of responsibility by making sure everyone was doing their job, and they really don't have anyone to fall back on if there is a mistake.

Sophie: I think the only thing that worried me was that everyone said they had to work a lot more hours than I had expected. Typically from at least 10 to 16 hours a day which is twice as much as most other jobs.

Neva: I would like to live the day of an engineer what a regular day for them is. Are they under a lot of pressure? What would be something that they suggest to be happy with the job you have.

Ayan: I would like to learn more about the typical life of an engineer both in the work place and at home. I want to know whether or not engineering interferes with many people's family and social life because of the fact that it is so time consuming.

A couple of girls raised questions about the ratio of men to women and its consequences. They wondered whether it was an advantage or a problem to be one of only a few women in engineering.

Remy: My view of engineering has changed over the past year, based on the number of women involved. The main disadvantage to me is the fact that the field lacks numbers of

women. The advantages to becoming an engineer are countless, because of the demand. I think that my generation has many more women who are interested in the field of engineering; the number of women should increase.

Inez: Other things I would like to learn about engineering is like why most women do not like engineering. Or why they do everything for men like cars, and stuff like that.

These results suggest that as the girls learned more about engineering, their interest in it grew. They expressed a desire to learn more about various fields of engineering, the kind of work that engineers do, and how they might connect some of their pre-existing interests with work in engineering. At the same time, they began to think more about how good one has to be in math and science to do engineering, how much time, pressure, and stress the work entails, and why it is that so few women go into engineering. These concerns are well-taken, but what is striking in the data is how easily and quickly the girls became excited and enthusiastic—*more interested*—in engineering.

Six Months Into FREE

About 6 months into the FREE project, we introduced the girls to the idea of designing their own small-scale engineering projects. In sharp contrast to the tentative and vague questions about engineering we could elicit for the career fair, girls' project ideas came quickly and in some detail. Here are the lists from 3 of the schools.

Build, make, or invent something:

- Laser sunglasses to melt snow
- Regenerate limbs
- Powdered water
- Automatic dog feeder
- Hover car
- Translator for different accents
- Always cold water bottle
- Implantable telephone
- Warm bubble
- Transportable biosphere to be placed on Mars
- Coma communicator
- Screen/computer application that transforms speech to sign language

- Glow-in-the-dark undergarments
- Multi-media desk
- Rolling desk (like a rolling chair)
- Key/remote finder
- Thermal clothing (can control temp to make warmer or colder)
- Head band that changes hair color
- Harry Potter style picture frame
- Laser car opener
- Remote controlled windows and doors

- Collapsible/foldable cowboy hat
- Stain resistant seat covers

- Electronic outfit organizer that creates outfits for you (can do multiple searches)
- Adjustable shoe heel (can go from flats to stilettos in seconds)
- Chewable flavored pen
- Key/remote finder
- Stylish color changing shirt
- Remote controlled mini fridge that delivers food/drinks
- Combined aromatherapy and sound therapy (e.g., waves) device
- Temperature controlled pillow (warm or cool)
- Quick way of getting rid of (or preventing) morning "bed head"
- Hair braiding tool
- Overnight hair growth
- Waterproof case for electronics (phone, iPod, etc.) that survives washing
- Indestructible American money like Mexican money (doesn't tear or break)

Meet a personal, family, or community need through engineering:

- ☐ Hover backpack
- ☐ Lotion that lasts all day
- ☐ Dialysis patient entertainment
- ☐ Dog propelled stroller or bike for kids
- ☐ Remote control cart
- ☐ Playground for handicapped kids
- ☐ Hydraulic backpack
- ☐ Self-propelled toothbrush
- ☐ Air cleaner/filter/scrubber for the top of smoke/pollution stacks
- ☐ Alternative to pesticides
- ☐ Turn signals/lights for wheelchairs

- Wallet for the blind that helps to organize money
- Money that allows blind people to determine the amount
- Voice activated/controlled computer

- Portable ramp for house and travel

- Air filter for entire school (removes odors from stink bombs, onions, etc.)
- Lotion that helps cure/alleviate arthritis
- Pedestrian overpass/bridge or underpass/tunnel on busy streets

Work on a safety issue through engineering:

- ☐ Ice grips
- ☐ Really hard/safe motorcycle helmet
- ☐ Motion sensor for cars

- Steel toed non-stick shoes for girls

- Protective body suit for kids (lightweight and flexible; waterproof, fireproof)

Create a virtual world:
- Weightless virtual world
- Mars station

- Baby translator (translates ooos and coos)
- Create an amusement park
- Build a mall

- Platform for a homecoming float modeled after plate tectonics

Enter a contest in engineering:
- Rube Goldberg

Start a business around an engineered product:
- Market products from other topic areas
- Solar powered jewelry

- Electronic notebook and pen
- A whistle to help find your car in a parking lot (your car whistles back)

Develop a presentation (Road Show, Film Show, Video, Billboard) about engineering:
- Road Show on "boys' think"

- Presentation for 9th grade girls about specific field of engineering

After discussions with the girls about the concepts, costs, feasibility, available expertise, etc. of the proposed projects, we and the girls agreed to pursue 26 of them (10 in CO; 12 in IA, 4 in OH) with the help of resource persons assigned to each group. The girls worked on their projects in small groups that met about once a month for most of the 2007-08 school year. At the end of the school year, we held a celebration for the girls to display their projects for family, teachers, and friends.

The selected projects fell into 2 main categories: personally enhancing and socially enhancing. Personally-enhancing projects included: adjustable high heeled shoes for women (a concept later named by *Time* as one of 100 best innovations of 2007); a robo-nanny [robot] toy for a teenage mother's toddler so the mother could be freed up to do her homework; flavored pen and pencil tops; attractive thermal clothing; glow-in-the-dark clothing; solar jewelry; and cameras-as-jewelry.

Socially-enhancing projects included: a water quality study for a popular recreation area; a money reader for the blind; an assistive robot; a playground for disabled children; a play table for a local library; a rain garden; a fish pond; a green kitchen; a green home; and environmentally friendly packaging. Two projects, creating a Rube Goldberg

machine and building a music box, were primarily for fun and the challenge to "see if we can do it."

By the end of the year, as the projects were completed and presented, the girls' engagement with engineering had taken a new form. In the projects, they began to take on some of the practices of engineering.

When engineers develop new or modified products, they proceed through a design cycle exploiting the synergy of professional and technical skills. The design-build-test cycle leads to a series of prototypes, which culminates in a product ready for public use. For a team of engineers to successfully launch a product, they must recognize customer needs and integrate evolving client demands into product specifications. Groups of engineers must also master project management skills, collaborative work techniques, and written and verbal communication. Technical knowledge and problem solving proficiency are equally important components of product development. Effective engineers are competent at incorporating all of these skills when pursuing complex systems and projects.

Here are brief vignettes of the girls' work and conversations in three project groups.

Adjustable High Heel Group

During the brainstorming phase of the project the girls identified a need for an adjustable high-heeled shoe. From personal experience, the group decided that women need a shoe that has a fashionable high heel for social events, and then can be transformed into a flat walking shoe after the event. Early in the project they discussed the problems related to combining style, comfort and flexibility into their shoe. They were very concerned that the shoe look good as well as function properly (the form followed function). Here are some of the topics the girls discussed as they generated alternative product concepts.

1. Design Issues: How would the shoe function?
    a. Example from 3-1-08, 12:30
        i. Mina, "Our heel would have to be two things, there would have to be something on the inside to catch the grooves." Aubrey, "Maybe like a spring, so if it falls, then it would like…." Mina, "That's a good idea. Like those Pez things, like you know how when you take one, another one comes up until it's empty. We could have one like that." Aubrey, "Oh, okay." Mina, "Yeah so you could just keep taking things out and the heel would go lower."
    b. Example from 3-1-08, 27:00
        i. Mina, "In order to make them, we'd have to make them to go slightly out like that at the top. The rest of them could be straight, but the top would have to be a little bit out. They'd also have to be longer right here so that they'd lock better."
    c. Example from 3-1-08, 1:17

        i. Mina, “When it goes flat you would have to take it off, and then when you have the heel in, since the shoe needs the arch when you put a heel, you would need to put a support in.” Rachel, “That’s a good question. Maybe that’s one of our questions for the expert: how to make the sole work with a heel.”
2. Aesthetics: Would the shoe function and look stylish?
    a. Example from 3-1-08, 21:50
        i. Mina states, “Our major question is how to make the heel go up on different levels. Not only what will work but what won’t be ugly, because a bunch of layers might look like Legos or something.” After working through the ideas Aubrey comes up with an idea to make the different levels more attractive, “So the last one can go with any level then. Maybe then you could have a slip cover in different sizes so you can’t tell.”

3. Consumer Assembly Issues: What would a girl do with the extra heel pieces, or how would she know where the pieces go?
    a. Example from 3-1-08, 22:00
        i. Mina, “We could put numbers on them, like level 1, level 2, level 3, cause like the first 3 would be like the same size but then they would get bigger.”

Subsequent discussions revolved around sketching prototypes of the heel, discussing materials needed and creating designs for how the heel would function. When describing details of the design, they would often compare their design concepts to specific items they see or use in daily life, such as crutches, plastic bottle lids, Pez dispensers and Legos. For example, Adilene shared this idea with the group, “Have you seen those little crutches? Like they have a little hole and then a pin that you click on and then off? Like those would work for the heel.” This design comparison approach continued throughout project development. Another example is when Mina shared an idea for the heel fastener, “We can have it [the heel] screw on the shoe, like you know how a lid is on a bottle, we could make it screw on like that.” The conversation continued, Mina, “I think right here there should be a circle on it, with some kind of tracking on it so that we could screw the heel in.” Researcher, “Some kind of grooves under the heel?” Mina, “Yeah, so you can screw it in to twist it in.” (See recording from 3-18-07, 11:37).

The overall group dynamic was reserved, with most members displaying an amiable social style. However, the presence of one assertive member would completely change the dynamic. Mina is a very outspoken individual, and this was amplified during group meetings as she would dominate conversations, make her ideas and thoughts known, as well as challenge other ideas given by others. As the project progressed, the other girls became more confident in their own ideas, started to discuss different concepts among themselves as well as with the resource expert, Mike, and began to advocate their own ideas on occasion. In one meeting during the middle of the project work, Mina was dominating the conversation and concept generation, but Aubrey also contributed with her own ideas. I [the researcher] was surprised because Aubrey was usually very quiet,

but it appeared that she felt strongly about her ideas this time and intended to push them. Aubrey and Mina were able to talk out their ideas for the heel and come to an agreement about how the structure of the heel should look. In the next meeting, Mina was absent, and Aubrey became the assertive member who explained their current ideas to Mike.

Even though the girls did not make an adjustable high heel prototype, they expressed their ideas clearly—in both English and Spanish—in a storyboard display and a verbal presentation at the end-of-the-year celebration.

Candy Pen-Top Group

The girls in this group noted that lots of students chew on the end of pencils and pens in class. Some group members noted that it would be nice if the pens had a better taste. Recognizing this need, the group decided to make a pen that had candy at the opposite end of the writing tip for people to eat.

The girls started with a plan to develop both the functional and design aspects of the new pen topper. Some of the very first discussions are about how the candy could move up and down within the pen. Three major design issues were identified by the group: 1) The girls wondered whether the pen will have a "twisty" or a "springy" to move the candy up and down; 2) whether the pen will have one or two caps (one for the pen and one for the candy); and 3) what kind of candy the pen will hold. While the girls discuss answers to these questions, they see the connection between the function of the candy topper design and the functioning of the pen. The following exchange illustrates that the girls not only combine the original pen design and new product design talk, but also understand that they cannot separate these items in an engineering project.

Comment [DK1]: Margaret: I am not sure that I understand what Julia is referring to here. Meaning: what did they initially find less important – the design of the candy?

Kiera: [Depending on] what type of candy it's gonna be, it would be better to do [a] twisty [motion to move the candy up and down].

Theresa: And the pen would… But I don't get it! Even if it's a spring, the [candy] cap is gonna go on and then you push it [the candy cap] and the candy's gonna come up…[but] how are you gonna put it [the candy] down?

Becky: No, no- cause like you need two things to operate cause if you want to use the pen, how are you gonna push it up?

Kiera: Or if there's a cap [for the candy] we don't need to do the pushy [to force the candy into the pen case].

Becky: Unless you like twist from the bottom to get the pen out, and [then] you pull this out to get the candy.

Kiera: Just a twisty [motion for the candy will work].

Becky: I know, but how are you gonna use the pen?

Angel: What do you mean?

Becky: How are you gonna use it?

Angel: The pen is gonna be like- no, the pen is gonna be like this.

Theresa: That's easier.

While the conversation prior to this exchange moved from discussion of the original pen design (how is the pen going to operate) to the design of the pen top (type of caps for the

candy and type of candy), here the girls joined these types of talk together. The girls have realized that the integration of the new candy top design with the original pen design cannot inhibit the function of the pen. Kiera notes that if the candy design is "twisty," the type of candy will matter. Similarly, Kiera notes the relationship between the potential for candy caps (to cover for sanitary reasons) and whether one will be able to push the candy up or not.

Comment [DK2]: Margaret: are these candy top caps? Or, pen caps? I got confused in the quotes above.

As the conversation and concept generation went on, there were occasional expressions of worry that the project was "too complicated" (19:20, R1, Mariene). At one point, Theresa noted that she didn't "think we can make the pen" and would like to stick with just making the candy (32:00, R2, Theresa). But Becky pushed back, saying "Everything's possible." This vacillation between what could realistically be done within the time constraints of the project and the potential scope of the project continued throughout the meetings. It was summed up by Mariene's when she said, "It's just about keeping an open mind. I mean, that's what engineering's all about, right?" This idea of an "open mind" stayed with the girls throughout the project, and they protested again later when I [the researcher] suggested that they stop worrying about making a prototype and just make a poster to show how they developed the idea for the candy pen.

Researcher: Right, right, are we gonna like take this pen apart? And cut it [and reconstruct it]? Or…are we just gonna make like a really awesome poster and be like: this is the process that someone would have to go through to make this [pen]?

The girls resist my suggestion with groans and no's. Although there have been moments of doubt and setbacks as material and equipment constraints were identified over time, the girls still want to try and make the product. In the spirit of brainstorming ways to overcome barriers, Kiera suggests a possible way to proceed.

Researcher: Yeah…if you guys never get to make this, because we can't find the mold, that's OK. I would love for you guys to actually make this, but know that it's part of being an engineer to [say that we] can't make it right now because the products are not out there that we need. Like, that mold may not be out there and you need that mold.

Kiera: Would it be possible for us to…contact a company that actually makes molds and ask them…?

Researcher: Totally, yeah, yeah!

Kiera: You could say like: Do you already make the mold or could they make it for us?

In the end, the girls decide to make the candy that would be placed inside the pen, design their pen with Google SketchUp, and present a poster showing the process of making the final candy pen.

Glow-in-the-Dark Group

Although the Glow-in-the-Dark group was initially made up of three girls (Stephie, Aerith, and Stacy), more then half of the FREE participants from Chavez would contribute or participate on this engineering project. During the brainstorming phase Stephie, Aerith, and Stacy remarked that glow-in-the-dark products loose their "glow" over time. The group then identified a need for lifelong glow-in-the-dark products. The three original girls decided to divide the initial project research into two parts—research on the chemical make-up of glow-in-the-dark materials and research into the currently available glow-in-the-dark products. Aerith volunteered to research the chemical make-up of glow-in-the-dark materials, since she was excited about chemistry based on a class that she was taking. Stephie and Stacy agreed to research glow-in-the-dark products available online.

For the third meeting after the project groups began, the FREE participants arrive and begin to fix themselves something to eat. About ten minutes into the meeting Aerith begins to describe her research on the chemical make-up of glow-in-the-dark materials to the rest of her group and one of the FREE researchers sitting with the group. Aerith displays new technical knowledge as she expresses her benchmarking results, product chemicals and consumer safety issues.

Aerith: It turns out that somebody beat us to the idea of a lifelong glow-in-the-dark thing.

Researcher: Oh yeah.

Aerith: The longest I found it can last is about twenty years.

Researcher: That's pretty good. I probably don't even like the same thing after twenty years.

Aerith: So I don't know what to do, but yeah. I have the chemical make-up of glow sticks on here. And the two basic things that are used are luminal and oxycilate. Luminal is not dangerous and oxycilate is used in diets so I don't think that it is very dangerous. Man, that's about it.

Researcher: So you found what they put in the glow sticks themselves? Do you know if you could use that same kind of chemical if it was touching your skin and stuff? Do you think it would probably be okay?

Aerith: Yeah, because luminal, they use that for … that kind of thing. I found that last night.

Stacy draws from her personal experience to confirm what Aerith is saying and addresses the issue of product safety.

Stacy: I accidentally broke a glow stick and it ruined my clothes and it got all over my hands.

Researcher: But nothing happened to your hands?

Stacy: No, they glowed but they didn't burn or anything.

The group's conversation then turns toward product conceptualization and aesthetics.

Researcher: So the recipe or the make-up of the mixture has both of these in it. Cool. And you found out that they use different chemicals for different colors. That's another thing that we haven't really thought about is what color you would want the glow-in-the-dark to be. I forgot that they had so many different colors because what I usually think of is that weird yellow green color. Even though other people have already come up with a chemical formula that lasts a long time, there are still other things that you could decide. You guys could still make lots of different kinds of products…with the same chemical without actually engineering a new chemical.

Researcher 2 (an Engineer): Engineering is not always about inventing a new thing, but applying the technology that you already have to new problems. It's okay that people have already done it.

The glow-in-the-dark group continues to consider a broad assortment of design considerations related to their project: how easy or hard it might be to get these chemicals, if they are okay to mix, concerns about the thickness/stiffness of the materials and how these characteristics might constrain the different products they could consider making, whether glow-in-the-dark materials could be in both liquid and solid forms, demands placed on different products, the purposes the product might serve, and who the audience would be. Throughout these discussions the girl consistently bring up experiences that they have had either at home or outside of school, for example Stacy had a glow-in-the-dark retainer which she referenced to convince her peers that glow-in-the-dark materials could exist in a solid form.

These vignettes illustrate some of the ways the girls engaged with engineering in their project groups. Consistent with the general principles of engineering design, they identified a need for the product and generated several product concepts; they searched for relevant technical knowledge and tried to put it to use; they considered both aesthetics and function of their products; they constructed a series of prototypes, they communicated, collaborated, and problem-solved with each other to develop ideas and manage logistics; and all but one group produced either an actual product or a detailed storyboard of the progress they had made. Through the projects the engineering language used by the girls did not become more sophisticated, nor did the groups delve into quantitative analysis typically associated with professional engineering projects. However, their exposure was equivalent to the initial design project experience encountered by first-year undergraduate collegiate engineers. The girls practiced the process of engineering design, while adhering to project constraints such as time, money, personnel, and resources already available.

Comment [DK3]: Margaret: We did not show this in the vignettes. But, it did happen. Do you still want to include?

Girls' Post-Project Reflections

To complete their projects, the girls had to struggle with limits of expertise and time, group members who didn't do their share, and competing priorities and demands, yet almost every girl said she knew more about engineering and was "more interested" in it than before doing the project.

After the projects were done and had been presented, we asked the girls: What do you know about engineering that you didn't know a year ago?

Ana: That it is more then just science and boring. It is creative and "artsy" and fun.

Jayde: My point of view on engineering has changed a lot. I believe now that engineering is exciting and interesting.

Ariane: It has changed a lot because before I saw engineering as a career, but now that's the career I want to do!

Remy: When I first heard the word engineer, I was not exactly sure what they did. I now understand that engineers work in almost every part of anything that has to be made; that is really exciting because it means that as an aspiring engineer there will be countless opportunities.

Sophia: My view of engineering has changed a lot during the past year. I used to think engineering was just about building bridges and making models of building plans, but I've learned that there are lots of other fun things that you can do like making a light up shirt for example. One thing I found out about engineering is that it is very broad so there are no limits to what you can create. It can be making something big like a plane or as simple as a shirt. It's creating anything you can imagine.

We also asked them: Are you more or less interested in engineering now than a year ago?

Ana: [More] because this makes me want to build and be an architecture engineer.

Ariane: I am more interested in engineering because I really like finding out how things work.

Natali: I am more interested in engineering now because I liked my project and would like to go more in depth on it.

Iliana: I'm more, I want to do computer engineering.

Sophia: I think I am a lot more interested in engineering now than I was a year ago because I got to see how many different things you can do and that lots of things are hands-on like our project which makes it much more enjoyable… My view of engineering has changed a lot during the past year. I used to think engineering was just about building bridges and making models of building plans, but I've learned that there are lots of other fun things that you can do like making a light up shirt for example. One

thing I found out about engineering is that it is very broad so there are no limits to what you can create. It can be making something big like a plane or as simple as a shirt. It's creating anything you can imagine.

Stacy: I am definitely more interested in engineering and would like to pursue more hands on type of research to see if engineering is what I want to do.

Chivas: I am a lot more interested because I actually got to see how it works more in detail.

Angel: I more interested in engineering now. Now I know is more than a boring job engineering can mean many things it has different fields and overall I honestly like it now that I know more about it. My view of engineering really changed big time. I used to see engineering as a boring career having to do a lot of math papers and etc. Turns out that engineering is much more than that; now I see it as a career of exploring with your ideas using your brains skills and everything else to create, invent, and discover many things.

Teresa: I believe I am a little bit more interesting in engineering, a year ago engineering didn't even passed through my head. My view of engineering changed a lot!! At first I thought that engineers would just stick to one simple product like build certain things and I was wrong about this, every little thing we use in our daily lives were at one point in a workshop of an engineer!

Mirele: I'm more interested in engineering now that I know more about the different fields.

Mariene: I still want to explore it and see what part of engineering would catch my interest. I am more interested to explore it and see if there is a place in the engineering world that I could be of use to.

Lizbeth: When I thought of engineering I thought of the color gray. Now I see it as something I could explore and the color blue.

Finally, we asked: For you personally, do you think the advantages of engineering outweigh the disadvantages or do the disadvantages outweigh the advantages? Why?

Angel: The advantages of engineering outweigh the disadvantages because so far I see engineering as a way to explore and let your ideas out; the only thing would be that it's not easy but now a days, what's really easy?

Mariene: I think the advantages outweigh just because I love to travel, I want to be a part of change, and I love the idea that I can help someone in the world have a more sanitary system, lifestyle or something of that sort.

Mirele: I definitely think that the advantages outweigh the disadvantages because you can do something for society and it looks interesting and I think it pays well.

Jane: The advantages outweigh the disadvantages- being an engineer would enable many opportunities as well as create a foundation for anything else I want to explore.

Lola: I think that the advantages outweigh the disadvantages because engineering is becoming more and more critical to our society today.

Toya: For me I say that the advantages outweigh the disadvantages because you can work on something that can change someone's life. Engineering challenges you to think outside the box and be a better team player than you have to be in some fields.

Sophia: I believe that the advantages of engineering outweigh the disadvantages because it is better to try to invent something great even if you fail or don't get the results you expected rather than not try because you are afraid something might go wrong.

Stacy: Depending on the type of engineering, but looking at bio med. I think the advantages outweigh the disadvantages because you get to help people while having fun inventing and researching. I think all the hard work definitely pays off, besides it's fun!!!!

Stephie: I think the advantages outweigh the disadvantages because there are so many types and people are always looking for people to be in engineering. Also as society becomes more advanced they will need more people to engineer new and more advanced technology.

Chivas: I definitely think that hands down the advantages outweigh the disadvantages because like I said engineering exists in EVERYTHING.

Outcome Numbers

We have worked with these girls for almost 3 years now. During that time, we lost girls for various reasons: some moved away, some decided they didn't want to continue or didn't have time to continue. Table 1 gives the numbers and percentages of girls who started in Spring 2007 (A), who were considering engineering at the start (B), who were still in FREE in August 2008 (C), who were considering engineering in August 2008 (D), who were considering engineering at both the beginning and end of the program (E), who did not consider engineering at either the beginning or the end (F), who switched away from considering engineering (G), and who switched to engineering (H) over the course of the program.

Table 1: Girls' Trajectories of Interest in Engineering as a Possible Career

	A	B	C	D	E	F	G	H
	Start Spr 07	Consider'g Eng at Start	Retained Aug08	Consider'g Eng Aug08	Stay in Eng	Stay in NEng	Switch Eng→ NEng	Switch NEng→ Eng
C	69	16 (23%)	38(65%)	15 (39%)	6(16%)	19(50%)	4 (11%)	9 (24%)

O								
IA	43	13 (30%)						
OH	20	2 (10%)	15(75%)	12 (60%)	2(10%)	3(15%)	2(10%)	10(50%)
	131	31						

Young women in high school and college are known to change majors and career choices often (refs.). The outcome measures in Table 1 are consistent with that trend. Some girls who started FREE with an interest in engineering dropped out of the program or switched their interest away from engineering. Some started FREE with little interest, later expressed an interest, and then turned away by the end of the program. Others developed an interest that has stayed with them, but in some cases, we know that they are not planning to become engineers, e.g., one girl intends to major in engineering in order to have an edge in the competition for medical school.

Nonetheless, we think it is impressive that 65% of girls who started in the program, almost none of whom knew hardly anything about engineering, continued for two years. Of those who stayed, nearly 40% were still considering engineering at the end, including 24% who were not considering it at the beginning. In addition (not shown in Table 1), approximately 60% of those who stayed said they were more interested in engineering at the end of the program than they had been at the beginning. IA ?? [Need to compare these figures to other programs] The majority in OH (10 out of 15 or 66%) were more interested in engineering at the end of program.

Conclusion

In the context of contemporary U.S. society, it is hard if not impossible to imagine how girls like those in FREE could develop interests in engineering, identities as prospective engineers, or a sense of themselves as engineers without purposeful, sustained interventions, similar to FREE, that offer supportive sites of engineering practice to them. There simply are not very many occasions—in school or out—for young people, especially girls, to learn about engineering. Not surprisingly then, the girls who started in FREE knew very little of what to expect and did not really know whether they were interested or not. Nonetheless, it was not hard to get most of them interested in the subject matter and some of them interested in a major or a career. Their interests took various forms, from wanting to learn about new fields, to acquiring new skills, to gaining confidence in new abilities.

If we want more people to be "interested" in something like engineering that the grooves of society do not ordinarily prepare them for, then we must proactively provide contexts in which those interests can be developed, supported, and nurtured. FREE is one of many programs that have found ways to do that. In our view, there is nothing particularly special about FREE compared to other programs designed for similar purposes (although successful programs do tend to have similar components (refs.)). What is important is that programs like FREE can exist, expand and flourish. Given the diversity of girls and

situations in the U.S., no one kind of program is likely to fit all cases. But without support and protections for many programs that provide sites of engineering practice for girls and young women, we cannot expect more to become interested and want to pursue these fields,

And, offering programs alone will not be sufficient. Lack of "interest" is not the only thing making it difficult for girls and women to pursue engineering. The papers that follow in this session take up some of the other issues.