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Inspiring girls to pursue STEM (ages three to thirteen): a recipe for a successful outreach event

Dr. Jodi Prosise, St. Ambrose University

Jodi Prosise is Chair of Engineering and Physics and an Associate Professor of Industrial Engineering and Mechanical Engineering. She earned her PhD in Biomedical Engineering at University of Minnesota and her Bachelor of Science in Mechanical Engineering at Iowa State University. She teaches courses in both Industrial and Mechanical Engineering at SAU, focusing in Engineering Graphics, Manufacturing, the Engineering Sciences, and Design. She was recently the PI of an NSF S-STEM grant to recruit rural students from Iowa and Illinois into STEM. Dr. Prosise mentors the collegiate chapter of SWE and organizes many outreach events encourage girls to go into STEM. She leads a study-abroad trip for engineering students to Brazil every-other-year, where students design, build, and implement assistive technologies for people with disabilities. Her research focus is to develop affordable upper limb prosthetics.

Dr. R R Romatoski, Saint Ambrose University
Dr. Susa H Stonedahl, St. Ambrose University

Susa Hardwick Stonedahl is an Associate Professor in the Department of Engineering and Physics at St. Ambrose University. She received her BA in Mathematics and Physics from Carleton College and her MS and PhD in Environmental Engineering and Sciences from Northwestern University. She teaches college and university physics courses. She is the faculty advisor to the St. Ambrose Women in Science and Engineering club, president of the Quad Cities' Sigma Xi chapter, and assistant director of the St. Ambrose undergraduate research program. Her primary research focusses on modeling and visualizing hyporheic water flow. Website: http://susa.stonedahl.com/

Dr. Yunye Shi Shi, St. Ambrose University

Yunye Shi is Assistant Professor in the Department of Engineering and Physics at St. Ambrose University in Davenport, Iowa. She received her PHD in Mechanical Engineering at the University of Iowa and her BS in Power and Energy Engineering at Huazhong University of Science and Technology in China. She teaches mechanical engineering courses including thermodynamics, fluid mechanics, heat and mass transfer, measurement and instrumentation, and capstone design courses. Her research interest includes biomass and MSW gasification, and economic analysis of thermo-chemical conversion paths.

Inspiring girls to pursue STEM (ages three to thirteen): a recipe for a successful outreach event

Abstract

To most it would seem that the U.S. (and the world) has improved leaps and bounds in their view of women in the workforce, yet representation of women in STEM remains low (only up 5% since 1993). In engineering specifically, women only make up 13% of the workforce (up from 9% in 1990). Gender stereotypes persist today, even after decades of campaigns to change that. It is critical that girls are shown at an early age that women can be engineers and scientists. This will help them combat false stereotypes and remove obstacles between them and a career in these fields. To this end, we have developed a highly successful outreach program that focuses on showing elementary and middle school-aged girls how fun and exciting a career in STEM can be. Hands-on activities emphasize creativity and allow girls to explore STEM without being judged, worrying about what grade they might receive, or dealing with the potentially inhibitory or suppressive presence of boys. The activities are designed to leverage girls' existing interests by showing how STEM fields require creativity, can improve lives, or can make the world a better place. Over one-thousand girls between the ages of 3 and 13 have participated in the last three years, and feedback demonstrates that the event has been successful at getting girls interested in engineering. This paper will detail how to plan and implement a successful event to interest young girls in engineering utilizing industry partners, student organizations, and fun girls-only activities.

Introduction

Careers in STEM-related fields will comprise much of the future job growth in the U.S. and worldwide [1]. Innovation in science and technology has been a key player in forming people's lives for over a century and will continue having large effects on society. Accordingly, growth in science and engineering occupations has experienced a sustained growth for more than 50 years, going from approximately 1.1 million workers in 1960 to 5.8 million in 2011, and even experienced growth during the recession [2]. Employment in science and engineering is expected to grow 18.7% from 2010-2020, compared to 14.3% for all occupations [2].

Despite the growth in employment in science and engineering from 3.3 million in 1991 to 5.8 million in 2011, the growth in number of women in the science and engineering workforce has only grown from 23% in 1993 to 28% in 2010 [2]. The number of women in the engineering work force, specifically, is only 13% (up from 9% in 1990) [2]. Yet women make up approximately 50% of the American population, and more than 50% of the college-bound population [3]. To most it would seem that the U.S. (and the world) has substantially improved their view on women in the workforce, yet representation of women in STEM remains low. Why is there this gap?

There are many hypotheses that try to explain the gender gap: gender stereotypes, hostile environments, personal values, parental influence, self confidence in STEM subjects, lack of female role models, etc. [4, 5, 6, 7, 8, 9, 10]. "Gender gaps in science and math performance have been closing, but gaps in STEM self-concept and aspirations remain large" [11]. In an attempt to increase interest among girls in STEM and combat negative influences girls may encounter, we started an outreach event for girls between the ages of 3 and 13 to foster their interest in STEM futures.

We designed our outreach event to focus on girls from a very young age because it is important to increase the pipeline of interest [8]. Data shows that girls lose interest in STEM field during middle school [9], and decide against pursuing STEM fields in high school or as they enter college [9]. Focusing on girls from a very young age makes this event unique to our region. Most regional events focus on older (high school) girls, many of whom have already made a decision for their career. Past studies have shown that even short-term outreach programs have a lasting effect on a girls' career direction [12]. The structure of our event focuses on hands-on activities, which girls find more interesting, appealing, and meaningful [13, 14, 15]. These activities emphasize creativity and allow girls to explore STEM outside of the classroom without worrying about what grade they might receive. It is a girls-only event because evidence shows girls gain better self-concept of ability and are more engaged in science in single-sex environments [16]. In addition, this event helps to encourage girls from low-income or diverse backgrounds because the event is completely free for participants to attend, with no requirement of affiliation with any organization.

By demonstrating fun and interesting activities, we expect this event to increase interest in STEM careers because it exposes girls to opportunities and support systems. Familiarizing and educating the participants with STEM concepts could also give them a confidence boost when they encounter these concepts again. The event is run predominantly by women in STEM fields, which along with the large number of girls also participating in the event should help combat stereotypes, provide role models, and thus show girls that engineering is a career path open to females. In summary, the goals of this event are to increase young girls' awareness of and interest in STEM fields, to create an environment where girls feel comfortable doing hands-on STEM activities without judgment, and to introduce girls to women role models with careers and aspirations in STEM fields.

Methods

Event description

Stations of activities are set up in a large room or set of rooms, all in close proximity (Figure 1). Stations are sponsored, organized, and implemented by local companies, student clubs (e.g., Society of Women Engineers and Women in Science and Engineering), and academic departments (e.g., Teacher Education). At each station, volunteers run hands-on activities that are intended to be interesting to girls and designed to encourage students to pursue careers in STEM. Different activities are chosen each year, and a database is kept in order to share activities with interested educators. A one-page flyer is provided for each activity that explains the STEM concepts and instructions on completing the activity (see Appendix A for examples). Examples of activities include:

- *Build the tallest tower:* Engineers often have constraints that they need to work with. In this project, time and materials were the main constraints. Engineers also solve problems, such as how to construct a tower. Students must decide which materials they would utilize from those given (paper, card stock, different types of tape) to make the tallest tower within a ten minute timeframe.

- *Laser engraving:* A laser engraver demonstration was given during which it created acrylic charms. Fun facts were shared about the engraver and students were given a chance to ask questions at the end. After the demonstration each girl was given a custom engraved charm bracelet the take home.
- *Frozen fractals:* The infinite nature of fractals was described to the older students and they cut out Koch snowflakes to three scales of symmetry. (Symmetry was described to younger students and they then cut out regular snowflakes.)

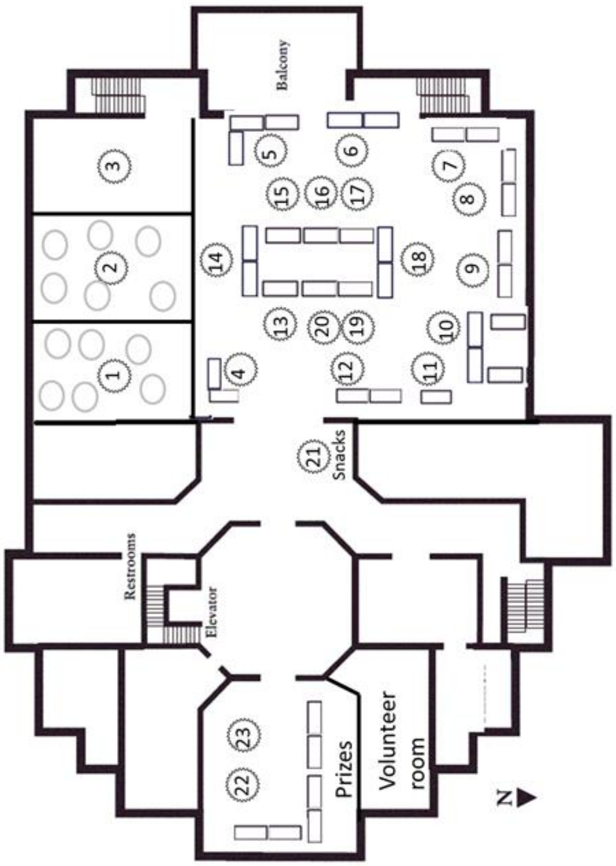

Figure 1: Layout of event stations, prizes, and volunteer room. Each activity is labeled with a number.

Girls and their parents visit stations at their own pace (Figure 2) and receive a mark on their gamecard for each activity they complete (Figure 3). Participants earn prizes for completing a certain number of activities, and everyone receives a certificate of participation (Figure 4). Both the stickers and the prizes provide positive reinforcement and encouragement. Two sessions are offered in order to accommodate the maximum number of participants, and pre-registration is required. Each session gives participants two hours to complete activities.

Figure 2: Participants and volunteers engaging in hands-on STEM activities

Table #	Activity	✓	Table #	Activity	✓
1A	Rubber Band Helicopter		12	Floodplain Hydrology	
1B	Merida's Bow		13	Goldilocks & the Three Bears	
2	Engineering Madness		14	Paper Frogs	
3	Print your own Tshirt		15	Big Hero Six	
4	Chemistry in Action		16	LED Bracelets	
5	Writing with Acids and Basis		17	Sound of Music	
6	Scribble Machine		18	Terrarium Exploration	
7	Working at a Nuclear Power Plant		19	Inside Out of Mirrors	
8	Skimmer Boats		20	Go Fish	
9	Gum drop bridge		21	Snacks!	
10	Renewable Energy		22	Finger Puppet Mafia	
11	Water Transportation		23	Flourish & Bots	

Figure 3: Gamecard for 2016 event. Each activity has a number corresponding to given location. Participants receive a mark for each activity completed in order to earn prizes.

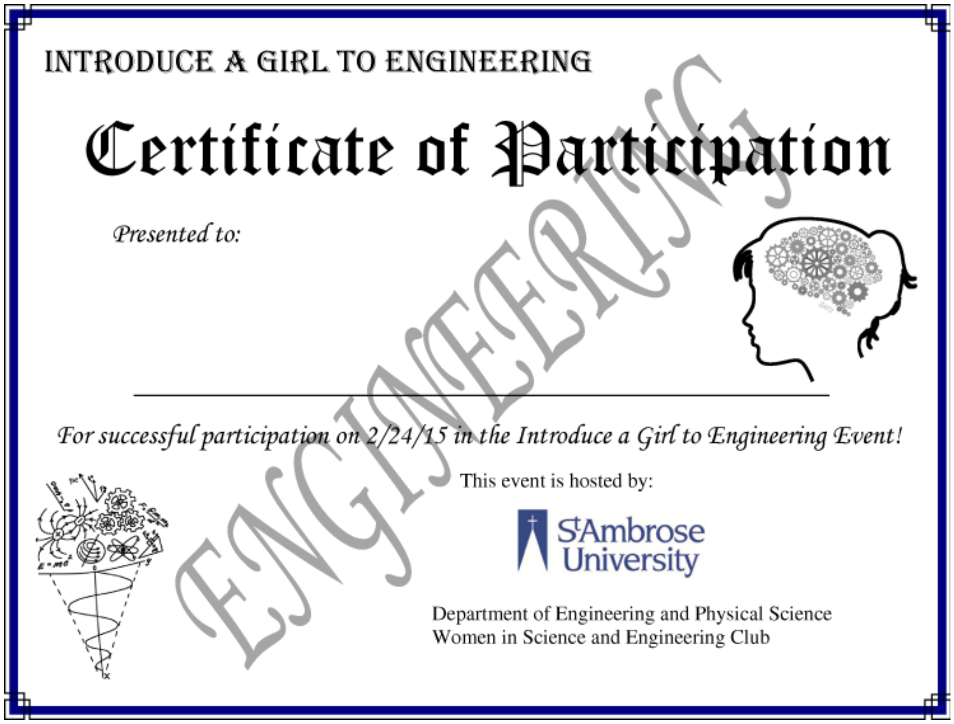

Figure 4: At the end of the event all girls receive a certificate for participating.

Planning and preparation

The timeline for planning and preparing the event (Figure 5) has been a key component to its success. The Society of Women Engineers Collegiate chapter works closely with the faculty sponsor starting three (3) months prior to the event. The group determines a theme for the year and develops at least six (6) activities to sponsor/host. Groups of two (2) students are responsible for each activity, including developing a one-page flyer and ordering all materials required. The group also assigns individuals responsibilities in soliciting donations for materials from local companies (Wal-Mart, Kwik Star, etc.). Bi-weekly meetings are used to assure progress is being made on tasks, with all tasks to be finalized at least one (1) week prior to the event.

Additional activities and sponsors are solicited by email through the faculty sponsor. An email is sent approximately two (2) months prior to the event to the department's list of industry contacts. Reminder emails are sent one (1) month, two (2) weeks, and one (1) week prior to the event. Three levels of support are offered (two monetary and one activity sponsor). Companies complete an online form with details regarding their sponsorship. The deadline for finalizing sponsorship to be included in online marketing materials is one (1) month prior to the event, and for print materials one (1) week. Volunteers from the community are solicited in the same email with a separate form. Confirmation emails are sent once a week for any new sign-ups.

Registration for the event is required and limited to 300 girls per session (due to fire code). An email is sent to past participants, local and regional schools, and a form is posted on the university website one (1) month before the event. Parents must complete a form with information about their daughter, including age, school, and contact information. The form also requires an electronic signature on a liability waiver (which includes a statement that participants are not to be left alone at the event) and a photo release. Registration typically fills within a week. Only female participants are allowed. An event reminder is sent to all registrants one (1) week and the day before the event.

The week before the event, flyers are printed and all materials for activities are secured and organized. On the day of the event, setup begins three hours before the start of the first session. Immediately following the event, the location is secured for the following year.

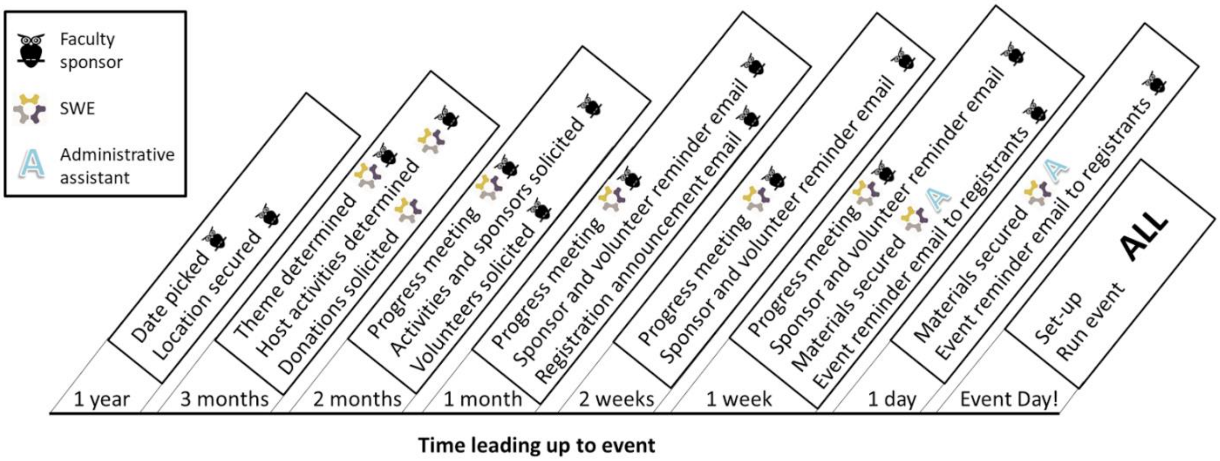

Figure 5: Timeline for event planning, preparation, and implementation. The person (Faculty sponsor, SWE members, or administrative assistant) responsible for each activity is denoted. Most activities begin approximately three (3) months prior to the date of the event.

Funding and support

The program started in 2013 and was funded, in part, from an NSF S-STEM grant, as well as departmental funds and donations. In the beginning, the demand was unknown, and the event was kept small with very little cost. Each year, donations are solicited from local engineering industry (e.g. John Deere, Arconic) and other companies with an interest in supporting youth education programs (e.g. Kwik Star, Hy-Vee, Panera Bread). T-shirts are sold (and printed on site as an activity), with proceeds going to support the program. A new design is created each year by students in the Society of Women Engineers (Figure 6). The event is adjusted to provide activities or amenities based on the amount of financial support available. A breakdown of the approximate costs associated with the event and how it is funded can be seen in Table 1.

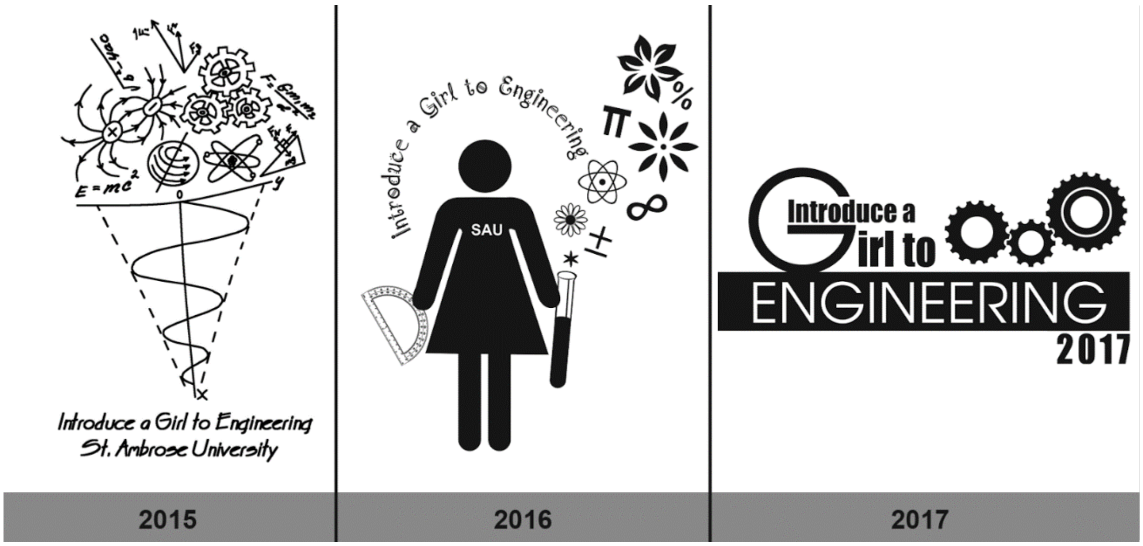

Figure 6: University students design t-shirts for the event, which participants may choose to purchase. Profits from the t-shirt purchases fund the supplies needed for the event. For the last two years, the t-shirt printing company has brought their silk-screening equipment to the event so participants can see the shirts being printed when they order them.

Table 1: Estimated cost breakdown for the event, including how it is funded.

Item	Cost	Fund	Type
Location/space	$0	University	In-kind
Materials for activities	$20-$50 per activity	Companies/organizations	In-kind Monetary
		T-shirt sales	Monetary
Snacks for participants	$100-$200	Companies/organizations	Monetary Product
Printing	$100-$200	University	In-kind
		Companies/organizations	Monetary
Prizes	$200-$500	T-shirt sales	Monetary
		Companies/organizations	Monetary Product
Food for volunteers	$150	T-shirt sales	Monetary
		Companies/organizations	Monetary

The success of the event relies heavily on the support of volunteers, both during the time leading up to the event (for planning and preparation) and during the event. The collegiate Society of Women Engineers chapter takes on the bulk of the planning and organization. Volunteers for the day of the event are solicited by email from university engineering and science students, university faculty (from engineering and other departments), local and regional engineering companies, and local high schools.

Data collection

Each year the number, age distribution, and school distribution of participants is tracked through the registration process. Similarly, the number and organization distribution of volunteers is also tracked. A research study has been initiated to obtain feedback regarding the success of the event in achieving the goals of increasing young girls' interest and awareness of STEM careers, as well as creating an environment where girls feel comfortable doing hands-on activities without judgment. This study will follow girls from their experience with the event through the years until college graduation, collecting information regarding their STEM attitude and extracurricular activities each year until a career path has been chosen. Additional details and survey instruments are available upon request.

Results

In the first year (2013), the interest in such an event was severely underestimated. It was expected that approximately fifty (50) girls would attend. Registration was not required, and attendance and other statistics were not carefully collected. Participation was overwhelming, with over two-hundred (200) girls estimated to have attended. In each subsequent year, registration has been required for all participants, volunteers, and sponsors in order to track interest and other data. Each year, participation has grown in nearly all areas (girls in attendance, number of activities, number of volunteers, and number of partners) (Figure 7). The number of girls participating more than doubled from 2014 (249) to 2017 (508), while the number of activities has nearly tripled (10 in 2014 and 28 in 2017). New activities are selected each year in order to accommodate girls that return each year (20% of attending in 2016 were returning and 35% in 2017). The number of volunteers has increased from 50 to 138, and the activities from 10 to 18. The number of companies involved with the program has also increased from 9 in 2014 to 16 in 2017. There was a slight decrease in involvement (down from 18 in 2016) this year, which is attributed to busy work schedules with contacts within companies. It will be beneficial to expand our contact database for future endeavors.

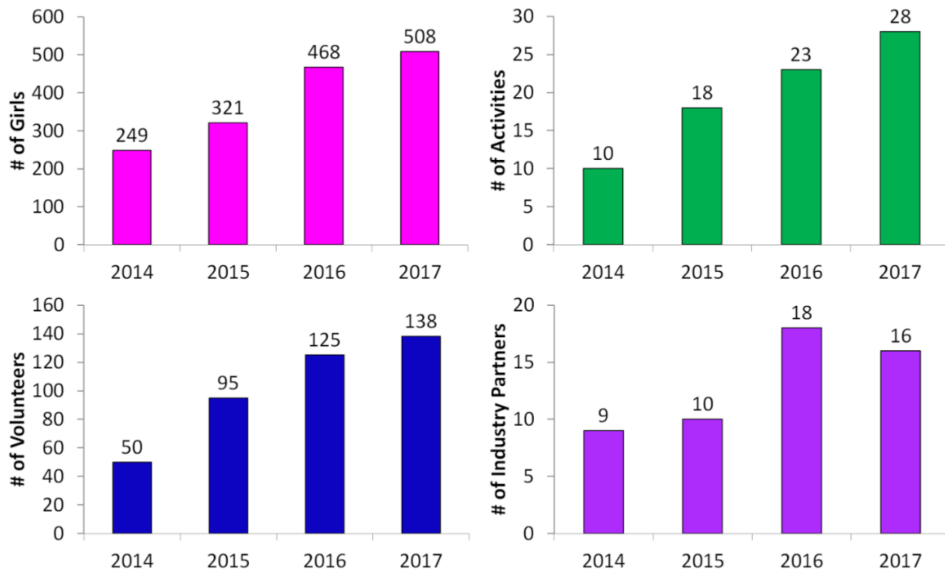

Figure 7: This event has grown tremendously since its inception, serving twice as many girls and involving almost three times as many volunteers and activities.

Conclusions and Future Directions

Our Introduce a Girl to Engineering event has been a terrific success, albeit by accident. When the program started, we expected approximately 50 girls to participate, but more than 200 attended the event. Each year the program has grown, and reached 508 girls last year. The event creates a terrific opportunity not only for young girls and their families to learn about STEM careers, but also for undergraduate engineering students and industry engineers to bond while volunteering. The number of sponsors and volunteers from the community has also increased over the years, showing the great interest and support of STEM outreach in the community. It’s clear to see that local organizations and companies support the need for a greater number of women in STEM.

Over the years we have learned many lessons as the event has progressed. First of all, don’t underestimate the interest in and passion for getting young girls interested in STEM! Requiring registration is paramount to being able to efficiently and adequately prepare the amount of materials needed for activities. While not necessary, motivating participants to complete activities to win prizes is fun and adds to their excitement. Make sure you have enough space and activities for participants to spread out while waiting and completing activities. Finally, having enough dedicated people to help with planning, registration, and implementation is the key to success.

We expect that by exposing young girls to fun and interesting activities in the absence of judgment, that it will increase their interest to pursue STEM careers. A research study has been initiated with the intent of following up with participants in future years to see if they pursue careers in STEM. The world needs more women in STEM fields and, therefore, more events and methods to get girls interested in the field. The interest in this event with both participants and community partners has been overwhelming, and we hope that more events like this, where young girls are exposed to fun and interesting activities surrounded by supporting women and mentors, will be developed and implemented all over the globe.

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Appendix A: Examples of one-pagers for activities

Superhero Coding

Learn the basics of coding without a computer. There are many steps involved in learning how to think like a programmer. These mazes, which can be solved with “code” using paper rather than a computer, illustrate 3 levels of difficulty and include a variety of programming concepts. Even young coders can try their hand at the first levels while level 3 begins to touch on concepts covered in an introduction to programming class.

How to Code

Your Superhero is stuck in the maze! On your Control Board, write the code or step-by-step instructions to help your Superhero escape. Keep in mind your Superhero can only do what you tell them, and they can only move one step at a time. A simple code might look something like this:

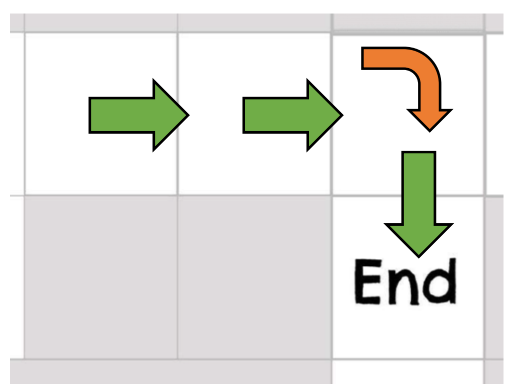
Control Board

Go **FORWARD**

Go **FORWARD**

Turn **RIGHT**

Go **FORWARD**



To exit the maze, list every step you think your Superhero will need. Then ask a friend to follow your instructions or follow them yourself. Did your code work or do you need to fix it? See how short you can make your code by using fewer commands. Can you make a code that will work in any maze?

See the back side for more ideas on how to improve your code!

Try the 3 Levels

Level 1: You can see the specific problem at hand and step by step walk your Superhero out of the maze. This level teaches the concept of perspective, or a point of reference different than your own. Your left may not be the same as the Superhero's left, but even the youngest kids can learn this valuable skill of switching reference frame.

Level 2: Using "For" loops simplifies your program by reducing the number of commands. With a "for" loop, you can say "Do this next command 7 times." You can use a loop that says "For ___ Steps" to do a command rather than just repeating the same card over and over. At the end of the "for" loop, you place an "End" card to note where the loop ends.

Level 3: The next level of coding is "while loops" and "if statements", which can reduce your program even further or give it more flexibility. As a programmer, you just need to consider all possibilities at any random location for the Superhero and decide the best generic sequence of actions. For example, what should the hero do if there's an opening to their left? What if they've hit a dead end? "IF" means definitely do this if the specified condition is true. "ELSE IF" means do this if the specified condition is true AND the "IF" and "ELSE IF"s that came before were not true. "ELSE" means do this if everything above has failed.

Questions to Consider

1. What problems did you face?
2. What if you had a bigger maze?
3. How can you keep your Superhero from wandering around too much?
4. What if your Superhero could remember where they have been?

Want to learn more?

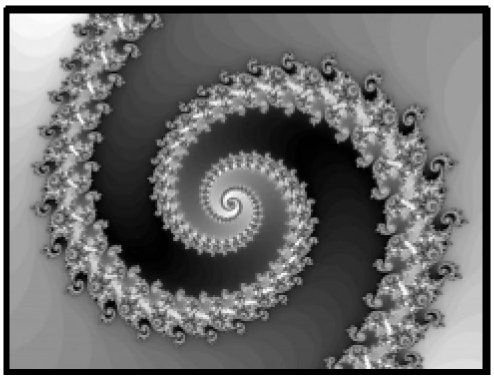
Visit Codecademy.com for more free coding experiences

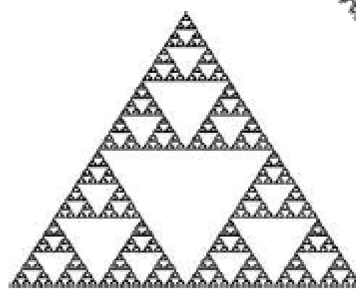
Frozen Fractals

St. Ambrose: Women in Science and Engineering Club

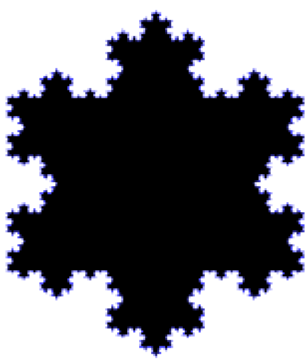
What are fractals?

Fractals are repeating patterns, that look the same at different scales. If you zoom-in on a fractal or enlarge it, it exhibits the same pattern as the original. This characteristic is called **self-similarity.** Real fractals are infinitely self-similar, meaning you can zoom-in forever and keep seeing the same thing.

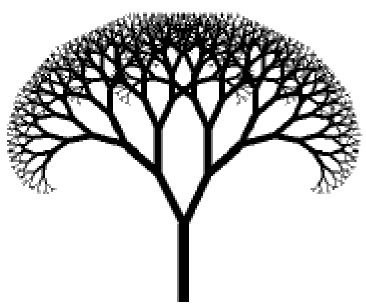


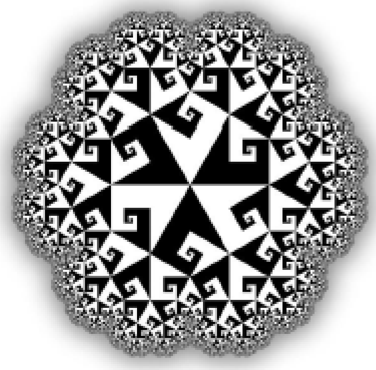


Sierpinski's Triangle



Koch Snowflake

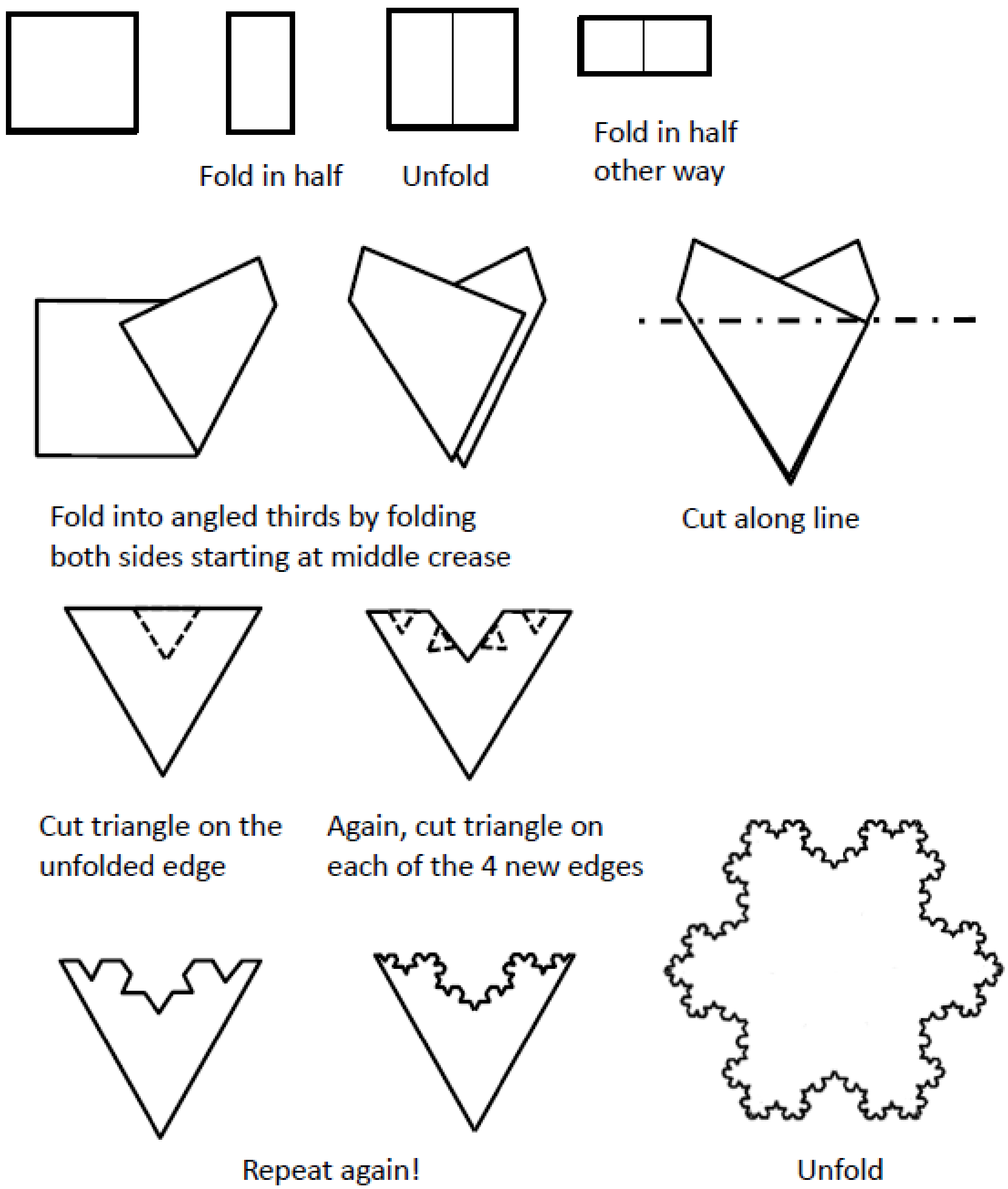




There are also lots of thing in nature that exhibit self-similar or fractal behavior. Seashells, river networks, ferns, … Look for it!

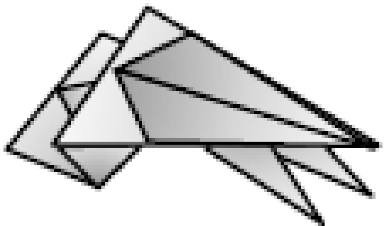
Directions for making a Koch Snowflake:

Materials: paper (cut to be a square), scissors, and ruler (optional)

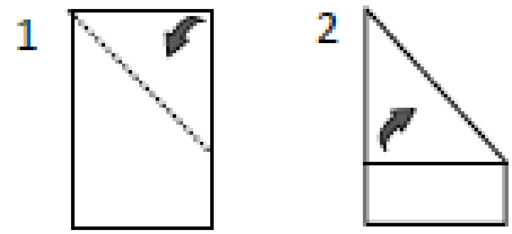


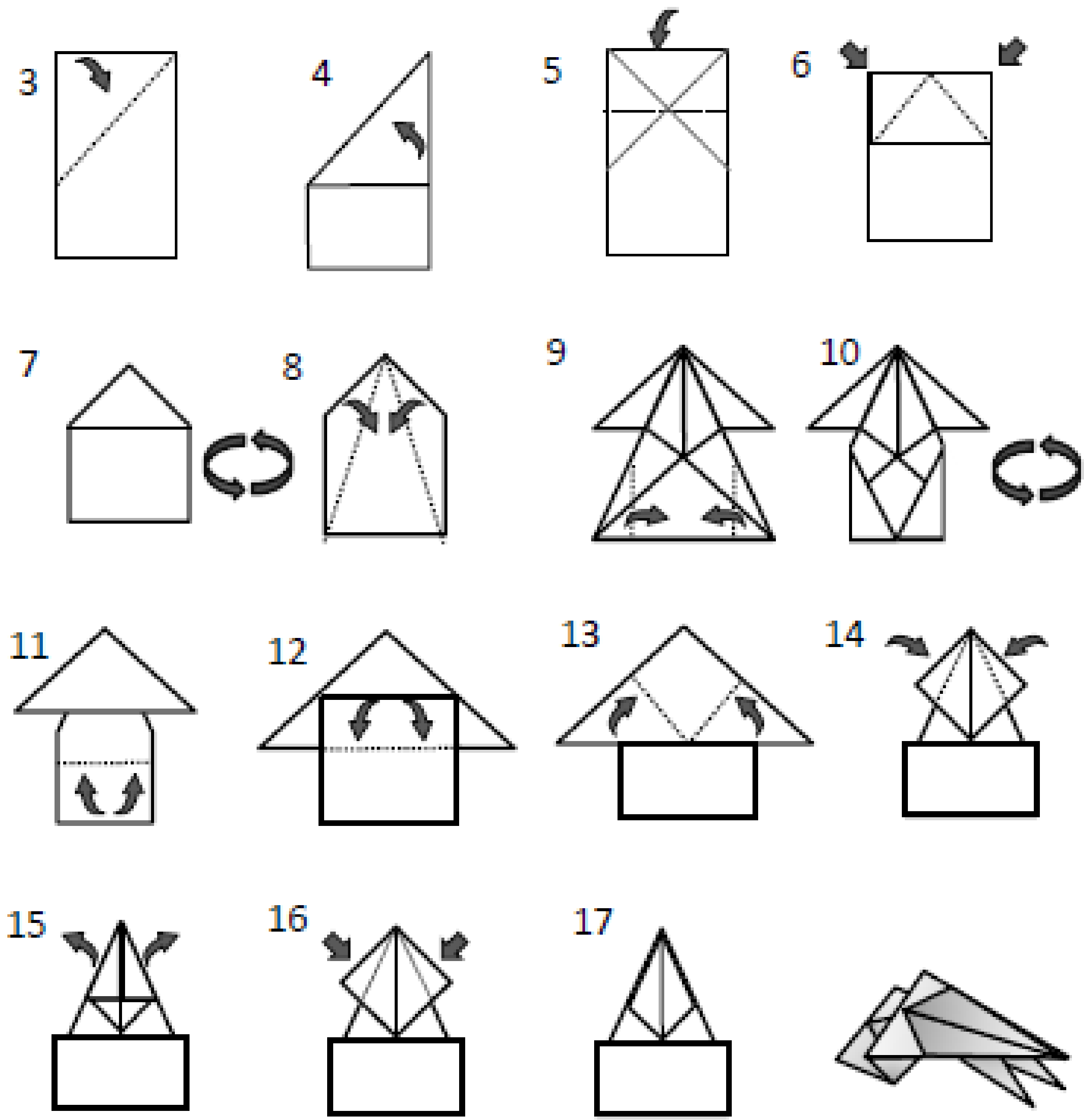
St. Ambrose: Women in Science and Engineering Club

Origami

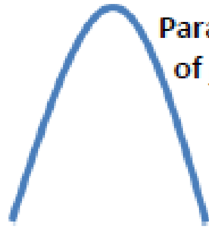


Jumping Frog





I. Why are frogs so happy?



Parabola of jump

II. What do you get if you cross a frog and a dog?

Fun Frog Facts

III. What do frogs wear on their feet

There are 17 species of frogs and toads in Iowa.[1]

A group of birds is called a flock, a group of cattle is called a herd, but a group of frogs is called an army. [2]

Frog coloration that helps it blend into its environment is called crypsis.

Every year that a frog goes into hibernation, a new layer of bone forms. So the age of a frog can be determined by the number bone layers it has (like trees).

Frogs have amazing skin that can breathe, absorb water and nutrients through it. This makes them sensitive to chemicals in the environment.

There is a frog in Indonesia that has no lungs – it breathes entirely through its skin. [2]

The biggest frog in the world is the Goliath frog. It lives in West Africa and can measure more than a foot in length and weigh more than 7 pounds – as much as a newborn baby. [2]

IV. What do you call a frog with no hind legs?

ANSWERS:
I. Because they eat what bugs them
II. A croaker spaniel
III. Open toad shoes
IV. Unhoppy
http://www.enchantedlearning.com/jokes/animals/frog.shtml

1-http://us.wow.com/wiki/List_of_amphibians_of_Iowa

2-http://www.smithsonianmag.com/science-nature/14-fun-facts-about-frogs-180947089/?no-ist

Bubble Trouble!

Water is a **polar covalent** molecule. This means that the electrons within the molecule are unevenly distributed, causing the molecule to have a slight **electric dipole moment** where one end of the molecule is slightly positive and slightly negative. Water contains both oxygen and hydrogen molecules. The oxygen has a slight negative charge and the hydrogen has a slight positive charge. This creates an intermolecular force called **hydrogen bonding**, which occurs when oxygen is bound to oxygen, nitrogen or fluorine in a solution. These intermolecular forces are what cause **surface tension** in water. Surface tension is what allows bubbles to form.

When other molecules are dissolved in water and interfere with the ability of the water molecules to stick together the surface tension can be greatly reduced. Molecules that do this are called surfactants. Soap is used as a surfactant during this activity to make the surface of the water more "Flexible" and less "Brittle", allowing us to make bubbles.

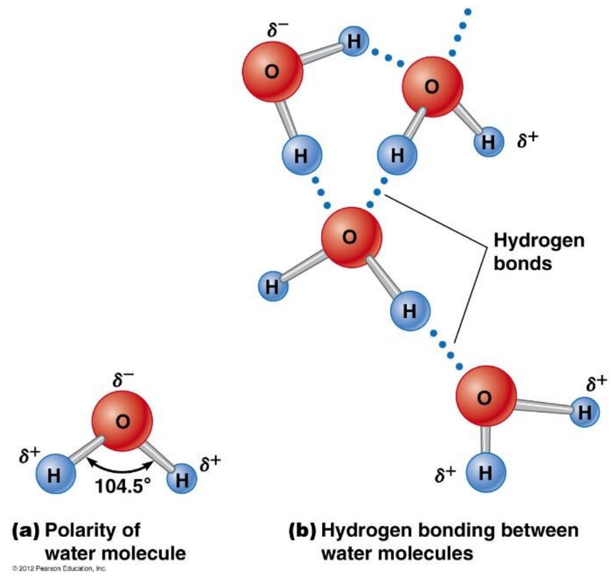


Figure 1 Hydrogen bonding in Water Molecules

The glycerin or corn syrup mixes with the soap to make it thicker. When the water that is trapped between the layers of soap in a bubble **evaporates** (or dries up), the bubble will pop! The thicker skin of the glycerin bubble keeps the water from evaporating as quickly. Adding glycerin or corn syrup makes bubbles stronger and helps them last longer. It makes super bubbles!

Materials Needed:

Plastic Disposable pipette, Scissors, Water, Dish Soap, Corn Syrup, A bowl, Microfiber Gloves

Instructions:

1. Begin by using scissors to cut the tip of the pipette's larger end, about one quarter of the way down.
2. Next, pour 3/4 cup of water and 1/4 cup dish soap into your bowl.
3. Then, add 1/8 a cup of corn syrup to your mixture. Stir until the corn syrup dissolves. While you stir, make sure no bubbles form at the surface.
4. You're almost ready to make a bubble! Put on your fuzzy glove and keep it dry so you can hold your bubble.
5. Next, dip the wide end of the pipette into the solution and blow into the other end. = Let your bubble float onto your gloved hand. Try not to catch it so it doesn't pop!
6. If you weren't able to blow a bubble or it popped too soon, add more dish soap to your solution and try again.
7. Now you're ready for the hardest step: try moving your hand to see if your bubble bounces. This may take some time, so stay patient.

Joke: What does the baby bubble call her father?

Answer: Pop-pa

Sources:

http://labratzscienceclub.com/corp/kitchen-chemistry/bubbles-and-surface-tension/

http://www.hometrainingtools.com/a/bubbles/

http://www.mun.ca/biology/desmid/brian/BIOL2060/BIOL2060-01-06/02_08.jpg

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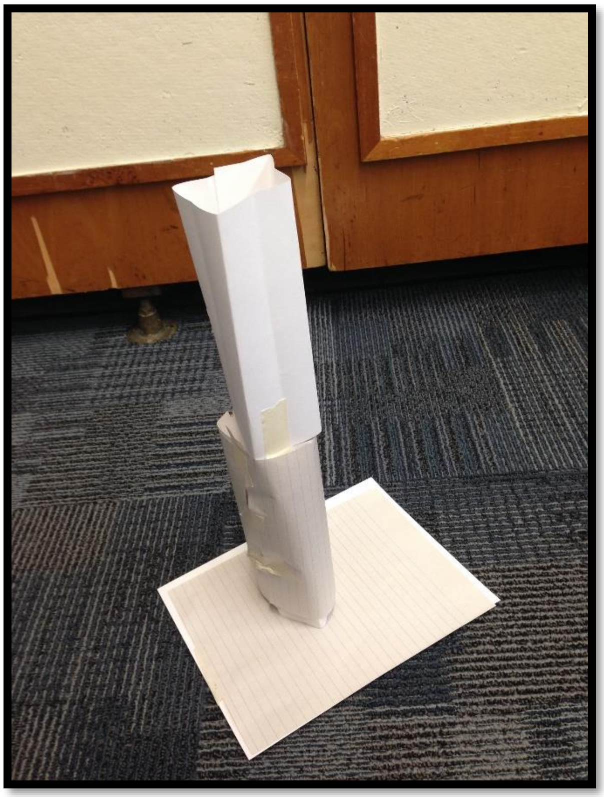
Build the Tallest Tower

Materials

- Computer Paper
- Colored Construction Paper
- Card Stock
- Duct Tape
- Scotch Tape
- Masking Tape
- Scissors
- Tape Measure



Instructions

This can be done alone or in groups. Each person or group gets the same amount of materials which include 10 pieces of computer paper, 5 pieces of colored paper, 3 pieces of card stock, 1 pair of scissors, and 3 different types of tape. A timer will be set for ten minutes and in that time, each person or team must try and build the tallest tower. The one with the tallest wins.

Lesson

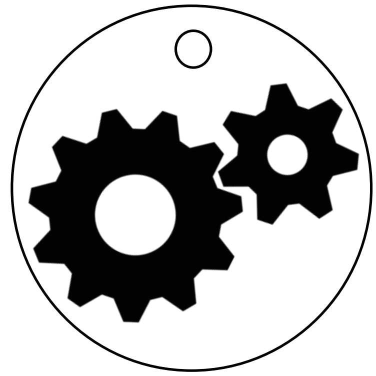
Like this activity, engineers often have constraints that they need to work with. In this project, there was only so much time and a limited amount of materials to use. Engineers also need to solve problems, such as when we decided how to go about the construction of our towers. A decision had to be made about what paper or tape to use and when. Using logical thinking we can all infer based off past or current knowledge, the pros and cons to each material and whether one is stronger, lighter or has any other benefits making it useful.

Future

In future construction of this project, the tower could be designed to withstand a set amount of weight, such as placing a book on top of it. This activity could also be done with less time or different materials.

Introduce A Girl To Engineering Day Activity:

Laser Engraving Demonstration



Demonstration:

A demonstration on using the laser engraver to engrave on acrylic charms will be given. Fun facts will be shared about the engraver and a chance to ask questions at the end. After the demonstration each girl will be given a custom engraved charm bracelet the take home. (See Design Above)

Materials:	Quantity
Laser Engraver	1
Pink Acrylic Sheets	(550 1 inch charms) approx. 5 sheets?
Bangles (Bracelets)	550 (100 we already have)
Jump Rings	550

Fun Facts!

-Laser engraving is a process where the laser beam physically removes the surface of the material

-You can choose or create any design to be engraved! Once you choose your design we upload it to a computer that is connected to the engraver!

-You can laser engrave almost any material! Glass, plastic, metal, etc.

-The laser creates high heat during the engraving process as well as gives off different fumes so it is important to have a ventilation system.

-The light that is given off from the laser can potential damage your eyes so it is

Popsicle Stick Catapult

Supplies Needed

- 2 Large Popsicle Sticks
- 5 Small Popsicle Sticks
- 4 Rubber Bands
- Marshmallows

How To:

1. Place the 2 large Popsicle sticks together and tie a rubber band around one end.
2. Place all 5 small Popsicle sticks together and tie a rubber band on both ends.
3. Place the 5 Popsicle sticks in-between the 2 larger ones and tie a rubber band around to secure in place (creating an x pattern).
4. Place a marshmallow on the end, push down, and LAUNCH!

4 Easy Steps!