Wearable Electronics:
A Medium to Increase Young Girls' Awareness and Interest in Engineering

By:

Jessica Uelmen

Rebecca Keyel, Faculty Advisor

University of Wisconsin, Madison

Masters of Engineering in Professional Practice

August 11, 2013

Table of Contents

1 The Need for a New Approach to Engineering Education

"The problem of gender diversity in engineering is ongoing and seemingly resistant to intervention" (Woodcock, Graziano, Branch, Ngambeki, & Evangelou, 2012, p. 496). While universities have graduated a higher number of females than males, women still earn fewer than half of the degrees in computer and information sciences and engineering (Freeman, 2004). Furthermore, while women make up almost half of the total workforce, only 8.5% of women work in an engineering field (Christman, Dell, & Garrick, 2010).

Research has determined that many girls do not view engineering as a field they can succeed in due to a lack of role models, lack of exposure to technical topics, engineering stereotypes, and low self-confidence in math/science aptitude. Many workshops and outreach events attempt to address these issues, with a goal of boosting interest among young women in engineering. However, these workshops attempt to conform girls to a pre-defined engineering mold, rather than focus on subject matter of interest to the demographic.

This traditional approach to engineering outreach for the sole purpose of evening out gender ratios is an ineffective approach to the problem. Girls should instead be presented with material that sparks their interest in engineering while allowing them to create projects that are relatable to them. The purpose of this research paper is to evaluate the effectiveness of wearable electronics as a medium for increasing young girls' interest in engineering.

2 Barriers to Pursuing Engineering Fields

2.1 Lack of Knowledge & Role Models

In a survey conducted by the New Jersey Pre-Engineering Instructional and Outreach Program, 25% of students surveyed were unable to correctly identify five types of engineers, while 30% did not respond or have a correct answer (Hirsch, Gibbons, Kimmel, Rockland & Bloom, 2003). This disconnect does not allow girls to see their own talents as a means to help them to succeed in the field (Jepson & Perl, 2002).

According to Becker (2010), "society fails to provide sufficient visible 'role models' of people who have succeeded as engineers rather than by switching from engineering to another profession" (p. 358). A lack of female role models only furthers the misconception that engineering is a profession primarily for men. A study conducted by Phipps (2002) found that all participants who had pursued engineering did so because of a family member's career in a scientific field or because they were encouraged by an outside source. Participants in the study further stressed that most girls think engineering is an unusual career choice and seek assurance from a woman who has already succeeded in the field.

2.2 Exposure to Engineering

When examining ability and interest in math and science, girls and boys do not differ at the elementary school level. Rather, gender differences become more evident during middle school with a clear divide at the end of high school (Leslie et al., 1998). This could be attributed to young children not being born with an inherent sense that engineering is for a specific gender; rather, they pick up these notions over time (Lane, Goh & Driver-Linn, 2011). As a result, girls who have not been exposed to engineering before entering high school are far less likely to pursue an engineering career.

2.3 Engineering Stereotypes

When girls are asked about pursuing a career in engineering, the most common stereotypical response is that the field is only for white males, Asians, and "nerds" (Kekelis & Ancheta, 2005). This "nerd" characteristic is perhaps the strongest deterrent for girls, who tend to be more concerned with popularity than their male counterparts (Leslie et al., 1998). This is referred to as the "stereotype threat," where women are hesitant to engage in activities that could cause them to be negatively judged by their peers (Rubelen, 2012). Even if a girl has positive experiences with technology, this threat is powerful that she still may not pursue a degree in fear of being labeled as a "nerd" (Kekelis & Ancheta, 2005).

Another common stereotype is that engineers constantly work long hours, are shut in a cubicle, and work in isolation (Jepson & Perl, 2002). With the number of choices available in today's job market, girls are even less inclined to choose occupations they do not want to relate to (Becker, 2010). Furthermore, because engineering is perceived to lack social characteristics, many girls do not view it as a creative or innovative field (Freitag & Thaler, 2011).

Currently, young women earn more undergraduate degrees than their male peers in the following fields: health professions and related sciences, psychology, education, accounting, and biological/life sciences (Freeman, 2004). Research suggests this is due to females wanting to work in a field that both helps make the world a better place and allows them to "nurture" others (Archer, DeWitt, Osborne, Dillon, Willis, & Wong, 2013). This stereotype is especially strange because many engineers design and create products that significantly improve the lives of people around the world on a daily basis (Pyke, Aburusa-Lete, & Budinoff, 2006).

2.4 Low Self-Confidence

During a robotics summer camp run by Voyles & Williams (2004), some interesting differences were observed in the attitudes of boys and girls. On the whole, girls showed a lack of self-confidence in their own ability by: seeking out and asking more questions of teachers, attributing success to the robot or computer software (not to their own abilities), and attributing failure to a lack of ability (rather than the difficulty of the task). These behaviors suggest that girls tend to be less confident in succeeding in engineering tasks, and if not encouraged, they would not pursue engineering of their own accord.

Tied to the "stereotype threat" mentioned in the section above, many girls operate under the assumption that boys should be inherently better at math and science. When analyzing national scores for AP Calculus AB testing, Danaher & Crandall (2008) found the pass rate for female test takers increased by 6.1% when asked for their gender after taking the test rather than before. They hypothesize that this increase in passing rates can be attributed to the fact that the "stereotype threat" has been removed. In other words, when girls are asked to confirm their sex prior to the test, there is a threat of confirming the stereotype that girls are worse at math than boys. When that threat is removed, girls mentally free themselves to perform at a higher level.

3 Increasing Awareness and Interest

When running an engineering outreach workshop targeted to young girls, Christman et al. (2010) identified the following success criteria:

1. Ensure that the girls are with their friends or can otherwise feel a sense of belonging in the group to which they are assigned.
2. Keep talk to a minimum and action to a maximum.
3. Connect the things they are doing to things they already know or care about.
4. Employ experienced volunteers that can relate well to the girls and create a fun atmosphere. (pp. 3-4)

These themes will be studied at length in the sections that follow.

3.1 Promote a Sense of Belonging

According to Becker (2010), "women go where they feel at home" (p. 359). This is especially true when girls face activities that do not interest them or they feel incapable of completing. In the program *Discover!*, which aims to promote girls' interest in engineering through single-sex activities, attendees contribute the success of the program to girl-only attendance (Watermeyer, 2012). Many participants expressed an increased confidence in returning to mixed-gender classrooms and realized engineering is not just for boys. Other participants commented that it was easier without boys because they did not need to worry about childish and sexist comments.

3.2 Hands-On Learning & Relatable Material

According to Hullema and Harackiewicz (2009), "Programs that emphasize personal relevance may be particularly empowering for students who are disengaged from school because of a lack of confidence." (p. 1410). Since many girls have an ingrained belief that boys are better at science, math, and engineering than girls (Watermeyer, 2012), providing a sense of empowerment is particularly necessary.

For example, mathematics is considered a key aspect of engineering, and demonstrating proficiency in this subject is paramount to success. According to Anwar & Altoona (2000), many math teachers are unable to relate how engineers use mathematics to solve problems, causing many students to lose interest. Therefore, the program run by Anwar and Altoona (2000) focused activities on how engineers use mathematics to solve real-world problems. The results from post-program surveys showed this hands-on approach increased girls' interest in pursuing mathematics as well as engineering.

Most girls put a lot of time and effort into their appearance and relate well with products that contribute to their attractiveness. Throughout a series of Saturday morning workshops, girls participated in hands-on labs where they created and presented their own personal care products by experimenting with chemicals and other materials (Secola, Smiley, Anderson-Rowland, Castro, & Tomaszewski, 2001). Post-program surveys cited that the girls almost unanimously voted the personal care product lab and presentation as their favorite activities. Encouraging girls to solve real-world, everyday problems showed a substantial increase in the girls' overall engineering knowledge and interest.

Another female engineering outreach program, Camp Reach, conducted short workshops where teams of girls develop a product that meets a real-world need (Demetry, Hubelbank, Blaisdell, Sontgerath, Nicholson, Rosenthal, & Quinn, 2009). Polled responses from an exit survey showed that girls had a 21.1% increased interest in engineering fields, with 49.5% of the 21.1% attributing it to working as a team to solve problems with their product. This is especially telling of the power of relatable material because even though the girls ran into problems, they felt the experience was rewarding and left with a positive outlook.

3.3 Highlight Females in the Field

With so few women currently working in engineering fields, most girls are unlikely to come in contact with a female engineer before graduating high school. Furthermore, even if a girl decides to major in engineering, she is unlikely to encounter a female professor (Pyke et al., 2006). Access to female mentors has been cited as one of the key components to attracting and retaining girls in engineering and sciences (Bloor, Krenitsky, & Wellenstein, 2007). Therefore, this obvious shortage in professional female engineers does not convey engineering as a desirable profession to younger girls.

A study by Dasgupta and Asgari (2004) sought to determine whether reading the biographies of women in non-traditional roles would affect the participants' preconceived notions about women in certain fields. When exposed to the success stories of women in non-traditional fields, the study concluded that the participants revealed a change in opinion from negative to positive about women succeeding and leading in these unconventional careers. More impressively, participants also saw the possibility of their own success in similar fields, something the girls did not consider prior to reading the biographies.

4 Wearable Electronics & Workshop Development

During an outreach session where girls were asked to build a prosthetic hand, traditional objects like LEGO Bricks and Meccano engines were pushed aside by the girls in favor of glitter and ribbons (Watermeyer, 2012). In other words, girls opted for aesthetic appeal rather than overall functionality.

This behavior is particularly telling about the areas of interest for young girls, demonstrating a preference of form to function. However, these two ideals need not be mutually exclusive. In many ways, crafting gave birth to capitalism with textiles being one of the first major industries (Bratich & Brush, 2011) and needlework being one of the only crafts throughout history to be practiced almost exclusively by women (Fisk, 2012). This not only gave females a place in the workforce, but also gave them a craft that was exclusively "theirs."

Compare this to science and engineering fields today, which are not only dominated by men, but are also believed by girls that they *should* be (Danaher & Crandall, 2011). Allowing young girls access to engineering topics using a medium that they can call their own might allow them to view engineering in a more creative context as well as help develop more technical confidence (Lovell, 2011). Electronic textiles, or e-textiles (also referred to as soft circuits or wearable electronics) are, according to Lovell (2011), “electrical circuits created using flexible conductive materials (such as conductive threads and fabrics) in conjunction with discrete electronics components (such as lights, batteries, switches, and sensors).” (p. 2). Essentially, if girls want to create clothing or accessories that light up or react to their environment, they need to learn the basics of both sewing and electrical engineering.

When asked what they want to be when they grow up, many girls answer “fashion designer,” which is a reflection of most girls’ traditional view of femininity (Archer et al., 2013). This further emphasizes the point that an e-textiles workshop would appeal to girls’ traditional view of femininity, while allowing them to experience some of the typical problem-solving techniques used by electrical engineers.

In order to test the efficacy of this theory, a short workshop was developed to introduce girls to electrical engineering using wearable electronics as a medium. In order to create a workshop with substance, girls would us basic math skills and circuit knowledge to create an LED bracelet. The sections that follow outline the approach and rationale for the content.

4.1 Key Concepts

Before the girls make their first stitch, it is important to impart key electronics knowledge. Without an electronics foundation, the girls would have no context when working on later activities. Since the workshop would be run in a short period of time, girls would experiment with the concepts of voltage, current, and resistance by connecting LEDs and resistors to batteries using alligator clips. This eliminated the need to introduce another foreign concept (the breadboard) and more accurately simulated the purpose the thread would serve in the final project.

Since girls also struggle with mathematics, another goal of the workshop was to demonstrate how engineers use math. Again, when working in a short timeframe, the material needed to be kept relatively simple so that attendees would not get overwhelmed. To meet these requirements, girls would calculate the minimum resistor value necessary to light up an LED when used with different voltages.

4.2 Format and Flow

In order to address the lack of role models in engineering fields, the workshop would begin with a self-introduction and follow with a Q&A session about what engineering is and why engineers love their jobs. After this introduction, the difference between regular electronics and wearable electronics will be explained.

In order to allow the girls to engage in hands-on learning, the girls would be encouraged to experiment with different combinations of batteries, LEDs, and resistors in order to observe their effects. Girls would also be encouraged to destroy LEDs so that the importance of resistors is made clearer. The importance of this exercise is two-fold: first, it provides tangible proof as to the importance of resistors; second, it encourages girls to experiment without fear of getting in trouble.

Girls would then use their newfound electronics knowledge to create a cuff bracelet out of felt and ribbon with LED adornments. The snaps that close the bracelet are used as a switch to connect power to the LEDs. A picture of the final product can be seen in Figure 1 below.

Figure 1: Wearable LED Bracelet. In the e-textiles workshop, the girls learned basic electronics concepts in order to create a cuff bracelet that lights up.

Additionally, the slides for the course were presented in a fun and engaging manner. In order to appeal to the artistic leanings of young girls, cartoon pictures of electronic components and hand drawings of schematics were used. Appendix A includes the slides used for the workshop, including detailed information listed in each slide's "Notes" section.

4.3 Measuring Success

While it was unreasonable to expect that the girls' attitude toward engineering would be completely changed during a four-hour workshop, there needed to be some method to measure the efficacy of the material. The simplest approach was to distribute short surveys before and after the course in order to determine if there was any change in perception toward engineering. Additionally, the content needed to be kept light so that the girls were not disengaged before the workshop began.

The questions used in these surveys were developed using questions posed in similar workshops by Hirsch, et al. (2003) and Christman, et al. (2010). A full list of questions can be found in Appendix B.

5 Workshop Execution & Findings

A four-hour workshop was held with nine girls aged 12-15. The workshop was run at Parallax Incorporated, and the attendees were the children and friends of Parallax employees. It was important to keep the workshop small so that attendees could receive individualized attention when constructing their bracelets. Furthermore, encouraging attendees to invite and bring their friends helped to promote the sense of belonging mentioned in section Promote a Sense of Belonging

The results from the workshop were mixed. In general, the girls did not seem to take the material or surveys seriously. This could be because attendees were on summer vacation, or because the workshop was conducted at their parents' place of work. While the workshop was not a complete success, the data collected was invaluable for developing future material. Detailed information on each aspect of the workshop, as well as lessons learned, are covered in the sections that follow.

5.1 Workshop Survey Results

Prior to the workshop, girls were given a survey in order to assess their level of interest in technical topics. Total sample size for the survey was seven girls, as two girls arrived too late in order to take it. The results are included in Table 1 below.

Table 1: Pre-Workshop Survey Results. Prior to the workshop, the level of girls' interest in engineering was assessed using short survey questions. Results are displayed as a percentage of total sample size (n=7).

Question	Yes	No	Maybe
I know what an engineer does.	57%	14%	29%
I have a friend/family member who is an engineer.	71%	29%	0%
I'm good at math and science.	57%	0%	43%
I find math and science boring.	71%	29%	0%
Engineers need to be geniuses.	29%	71%	0%
Engineers make a lot of money.	71%	0%	29%
Engineers spend most of their time working in front of computers.	14%	86%	0%
Engineers aren't very social.	14%	71%	14%
Engineering make products that help people.	100%	0%	0%
Engineers aren't creative.	0%	71%	29%
I want to be an engineer.	29%	14%	57%

Results from the survey depict an interesting deviation from the standard responses discovered in research. This could be due the fact that the majority of attendees (71%) have a friend or family member who is an engineer, and as a result may not view engineering as a fixed set of stereotypes. Specifically, many girls thought engineers to be both creative and social, and do not spend most of their time in front of computers; traits most individuals do not associate with engineers.

Interestingly, while many girls had quasi-positive associations with engineering, only 29% expressed definitive interest in pursuing engineering as a career, with 57% unsure. When asked to elaborate on their reasons for wanting or not wanting to pursue a career in engineering, most girls answered that they were "too young" to know what they wanted to be when they became an adult.

A post-workshop survey was intended to evaluate any change in attitude among the attendees. However, due to challenges with workshop execution, there was not any time to distribute the final survey. Even without the results from the post-workshop survey, the success and effectiveness of the material was easily ascertained. This is discussed at length in the sections that follow.

5.2 Workshop Discussion and Results

As mentioned previously, the results from the workshop were mixed. At the end of the class, five of the total nine girls left with a working project. This was due to a variety of variables: not enough time, spontaneous attendee deviation from the original project plan, and lack of instructional assistants. Workshop successes and challenges are discussed at length in the sections that follow.

5.2.1 Positive Response to Hands-On Experimentation

The beginning of the workshop focused on teaching key electronics concepts. Girls were encouraged to connect LEDs to a variety of batteries and resistor values in order to observe their effects.

This portion of the workshop went over exceedingly well; girls were engaged and eager to share their ideas and conclusions. The ability to perform their own experiments and learn from their mistakes gave them the confidence to try almost anything, which could be attributed to the fact that the girls were encouraged to (safely) destroy LEDs. As a result, the girls demonstrated a good understanding of the effects of different voltages and resistor values on the brightness of an LED.

5.2.2 The Individualistic Nature of Girls

Most girls enjoy expressing their individuality. To help facilitate this, many different colors of felt and LEDs were selected so that the girls could personalize their bracelets. However, it was not anticipated that many girls would desire to create projects that deviated from the planned activity.

Rather than complete the bracelet, many of the girls wanted to create hair bows instead. At the time of the workshop, it seemed that this deviation would be easy to accommodate and would give the girls real engineering experience. In retrospect, this was the main point of failure for the course. Allowing the girls to have full creative license, while lacking a solid foundation in both sewing and electronics, resulted in messy and non-functional circuits.

5.2.3 A Need for Instant Gratification

Girls today live in a world of instant gratification. Between laptops and smartphones, the solution to virtually any problem is always at their fingertips. As a result, the girls were not prepared for the amount of work required to make a functioning product. They simply saw an object they desired, and expected it to be completed quickly and easily.

5.2.4 Completion Percentage

Due to the number of girls creating projects that deviated from the original plan, five of nine left with functional projects. However, all but one of the girls who left with a non-functional project expressed interest in taking materials home to try again. After speaking with parents after the course, it was determined that two girls continued to experiment at home. This emphasizes the key finding of the workshop:

> *While the project may not have been successful, the workshop did succeed in inspiring girls to keep working with electronics. This proves that wearable electronics is a viable medium for increasing girls' interest in engineering.*

5.3 Key Takeaways

Running a workshop with young girls was insightful, and identified many areas for improvement. Some of the key takeaways from the workshop are discussed at length in the sections that follow.

5.3.1 Increase Workshop Length

In short, four hours was not enough time for a workshop. The importance of electronics concepts could not be fully emphasized, and as a result girls were still confused when it came time to connect everything.

A more appropriate approach would be to span the material out over 2-3 days. The first meetings would focus on the basics of electronics, ensuring that there is a solid foundation of understanding. This longer workshop could be run consecutively if conducted at a summer camp, or across a series of Saturdays if being run as a community event.

5.3.2 Emphasize the Importance of Short Circuits

The primary problem with the girls' projects was the continuous crossing of positive and negative connections. This problem could be solved by a longer workshop, or more effectively, by introducing the conductive thread during initial circuit experimentation. Having the girls use conductive thread in lieu of alligator clips (which are insulated) will allow the girls to see what happens when a positive and negative thread are crossed. Experiencing this phenomenon prior to stitching a circuit may prevent the girls from sewing connections that are too messy to fix.

5.3.3 Complete More Prep-Work

Girls had particular trouble trimming the LED leads and bending them into circles. This exercise wasted a lot of time and required instructor intervention. Completing this action prior to the course would help to save time and keep the final product looking neat.

5.3.4 Smaller Student/Teacher Ratio

When working with wearable electronics, it is incredibly easy to get into trouble fast. If the instructor does not catch problems as they are happening, it can take a long period of time in order to set the circuit right. For this reason, a much smaller student/teach ratio is required.

For future courses, a 3:1 ratio is recommended. This allows the instructor to remain at the table throughout the entire time the circuits are being built. She can also easily build the same circuit as the students and share tips and tricks during the process. This increase in instructors will also provide more individualized time with engineering role models.

5.3.5 Modify for Classroom Use

Originally, it was desired to utilize this material in the classroom. However, due to the reasons listed in the sections above, this does not appear to be a viable option. Specifically, one teacher would have an incredibly difficult time keeping an entire classroom of students on track.

Online video tutorials could make the material more suitable for classroom use. This would allow students to follow along with the lesson at their own pace, incorporating checkpoints where the student would need to get instructor approval before moving to the next step. However, this would require the instructor to be knowledgeable about e-textiles, which would not be common among middle and high school teachers. In order to increase instructor confidence, workshops specifically for educators can be developed to train teachers on techniques for using e-textiles in the classroom.

6 Future Development

Research has shown that providing relatable material helps engage girls in engineering activities (Secola et al., 2001) and helps them perceive engineering as a field in which they can be successful (Christman et al., 2010). E-textiles provide an ideal, relatable means for increasing girls' interest in engineering by allowing them to use engineering skills to create fashionable objects.

While the workshop determined that the material might not be suitable for classroom use as-is, it is still believed to be useful for after-school programs, sewing clubs, hackerspaces, and scout troops. Wearable electronics is an ideal method for combating the stereotype threat. The material can be taught outside of the classroom and in a single-sex environment, with a goal of increasing the confidence of young girls in the areas of math and science. In this manner, girls will be in a better position to succeed when returning to mixed-gender classrooms.

This material will continue to be developed into a longer and more detailed workshop. Pilot programs will continue to be run with local organizations in an effort to constantly evaluate its effectiveness. Teacher trainings will also be conducted to help improve the material so that it is suitable for the classroom.

7 References

Anwar, S., & Altoona, P. S. (2000). A Contemporary Science and Engineering Program for Middle School Girls. *ASEE Annual Conference* (pp. 147–153).

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). "Not girly, not sexy, not glamorous": primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society*, *21*(1), 171–194. doi:10.1080/14681366.2012.748676

Becker, F. S. (2010). Why don't young people want to become engineers? Rational reasons for disappointing decisions. *European Journal of Engineering Education*, *35*(4), 349–366. doi:10.1080/03043797.2010.489941

Bloor, A., Krenitsky, L., & Wellenstein, M. J. (2007). Work in progress - women in technology: An initiative to reach females in rural Wisconsin. *2007 37th annual frontiers in education conference - global engineering: knowledge without borders, opportunities without passports* (pp. S2H–14–S2H–15). IEEE. doi:10.1109/FIE.2007.4418079

Bratich, J. Z., & Brush, H. M. (2011). Fabricating Activism: Craft-Work, Popular Culture, Gender. *Utopian Studies*, *22*(2), 233–260.

Christman, J., Dell, E., & Garrick, R. (2010). Increasing Girls' Interest in Engineering by Making it Fun. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Danaher, K., & Crandall, C. S. (2008). Stereotype Threat in Applied Settings Re-Examined. *Journal of Applied Social Psychology*, *38*(6), 1639–1655.

Dasgupta, N., & Asgari, S. (2004). Seeing is believing: Exposure to counterstereotypic women leaders and its effect on the malleability of automatic gender stereotyping. *Journal of Experimental Social Psychology*, *40*(5), 642–658. doi:10.1016/j.jesp.2004.02.003

Demetry, C., Hubelbank, J., Blaisdell, S., Sontgerath, S., Nicholson, M. E., Rosenthal, E., Quinn, P. (2009). Supporting Young Women to Enter Engineering: Long-Term Effects of a Middle School Engineering Outreach Program for Girls. *Journal of Women and Minorities in Science and Engineering*, *15*(2), 119–142.

Fisk, A. (2012). "To Make, and Make Again": Feminism, Craft and Spirituality. *Feminist Theology*, *20*(2), 160–174. doi:10.1177/0966735011425302

Freeman, C. E. (2004). *Trends in Educational Equity of Girls & Women, 2004* (p. 109). Washington, DC: U.S. Government Printing Office. Retrieved from https://www.ets.org/Media/Research/pdf/conf_achgapwomen_freeman.pdf

Freitag, D., & Thaler, A. (2011). Intervention models towards more diversity in engineering education. *2011 IEEE Global Engineering Education Conference (EDUCON)* (pp. 518–522). IEEE. doi:10.1109/EDUCON.2011.5773185

Hirsch, L. S., Gibbons, S. J., Kimmel, H., Rockland, R., & Bloom, J. (2003). High School Students' Attitudes to and Knowledge About Engineering. *Proceedings - Frontiers in Education Conference*, *2*, 7–12. doi:10.1109

Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science (New York, N.Y.)*, *326*(5958), 1410–2. doi:10.1126/science.1177067

Jepson, A., & Perl, T. (2002). Priming the pipeline. *ACM SIGCSE Bulletin*, *34*(2), 36. doi:10.1145/543812.543826

Kekelis, L., Ancheta, R. W., & Heber, E. (2005). Hurdles in the Pipeline: Girls and Technology Careers. *Frontiers: A Journal of Women Studies*, *26*(1), 99–109. doi:10.1353/fro.2005.0013

Lane, K. A., Goh, J. X., & Driver-Linn, E. (2011). Implicit Science Stereotypes Mediate the Relationship between Gender and Academic Participation. *Sex Roles*, *66*(3-4), 220–234. doi:10.1007/s11199-011-0036-z

Leslie, L. L., Mcclure, G. T., & Oaxaca, R. L. (1998). Women and Minorities in Science and Engineering: A Life Sequence Analysis. *The Journal of Higher Education*, *69*(3), 239–276.

Lovell, E. (2011). *Getting Hands-on with Soft Circuits* (p. 28). Retrieved from http://web.media.mit.edu/~emme/guide.pdf

Phipps, A. (2002). Engineering Women: The "Gendering" of Professional Identities. *International Journal of Engineering Education*, *18*(4). Retrieved from http://www.ijee.ie/articles/Vol18-4/IJEE1290.pdf

Pyke, P., Aburusa-Lete, L., & Budinoff, C. (2006). Where the Girls Are: Applying an Integrated Marketing Approach to Attract Girls into Engineering Programs. *ASEE Annual Conference and Exposition, Conference Proceedings*. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Where+the+Girls+Are+:+Applying+an+Integrated+Marketing+Approach+to+Attract+Girls+into+Engineering+Programs#0

Rubelen, E. W. (2012). Gender Disparities in STEM Subjects Pronounced in the United States. *Education Week*, *31*(36), 8–9.

Secola, P. M., Smiley, B. A., Anderson-Rowland, M. R., Castro, M., & Tomaszewski, B. (2001). Assessing the effectiveness of Saturday Academies in an engineering outreach program. *31st Annual Frontiers in Education Conference. Impact on Engineering and Science Education. Conference Proceedings (Cat. No.01CH37193)* (Vol. 3, pp. S1F–16–21). IEEE. doi:10.1109/FIE.2001.964003

Voyles, M., & Williams, A. (2004). Gender Differences in Attributions and Behavior in a Technology Classroom. *Journal of Computers in Mathematics and Science*, *23*, 233–256. Retrieved from http://www.editlib.org/p/11488

Watermeyer, R. (2012). Confirming the legitimacy of female participation in science, technology, engineering and mathematics (STEM): evaluation of a UK STEM initiative for girls. *British Journal of Sociology of Education*, *33*(5), 679–700.

Woodcock, A., Graziano, W. G., Branch, S. E., Ngambeki, I., & Evangelou, D. (2012). Engineering Students' Beliefs About Research: Sex Differences, Personality, and Career Plans. *Journal of Engineering Education*, *101*(3), 495–511.

8 Additional Resources

In order to help develop the project and material for the workshop included in : Workshop Material, additional sources were consulted for ideas, terminology, and general information. These sources are listed below.

Eng, D. (2009). *Fashion Geek* (p. 128). North Light Books.

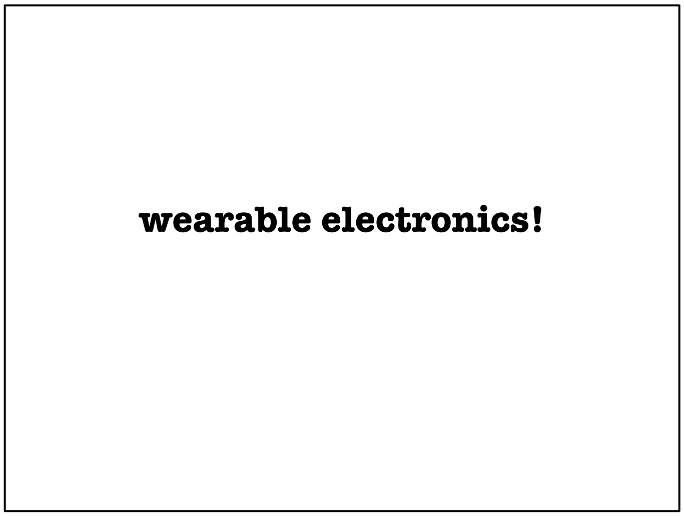
High-Low Tech Lab. (n.d.). Retrieved July 15, 2013, from http://hlt.media.mit.edu/

Pakhchyan, S. (2008). *Fashioning Technology* (p. 240). O'Reilly Media.

Stern, B. (2013). Conductive Thread. Retrieved May 02, 2013, from http://learn.adafruit.com/conductive-thread/

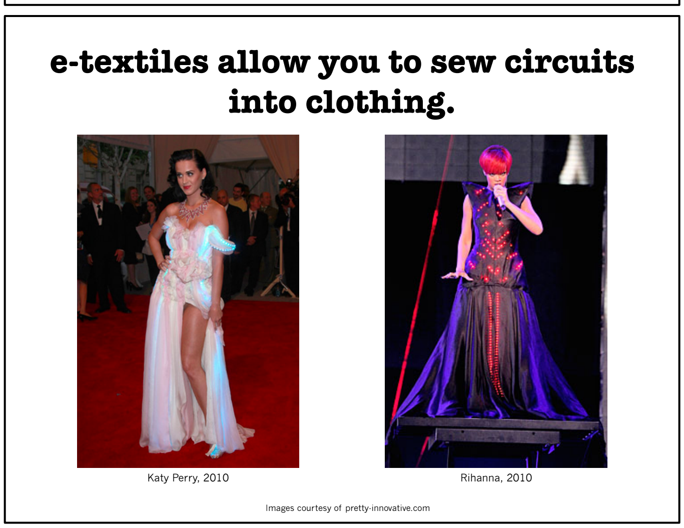
Appendix A: Workshop Material

Included in this appendix are the slides and notes used for the wearable electronics workshop.

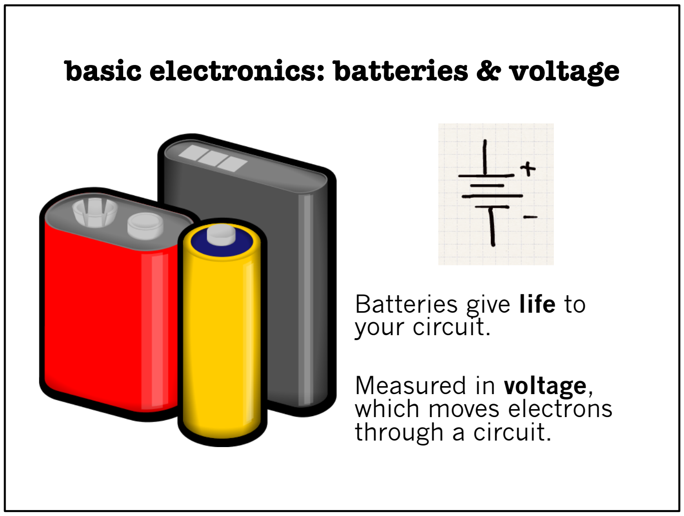


Introduction of self: how I became an engineer & why I like it.

We use electronics every day to make calls, cook food, surf the internet, or watch TV. Engineers design and bring these products to market.

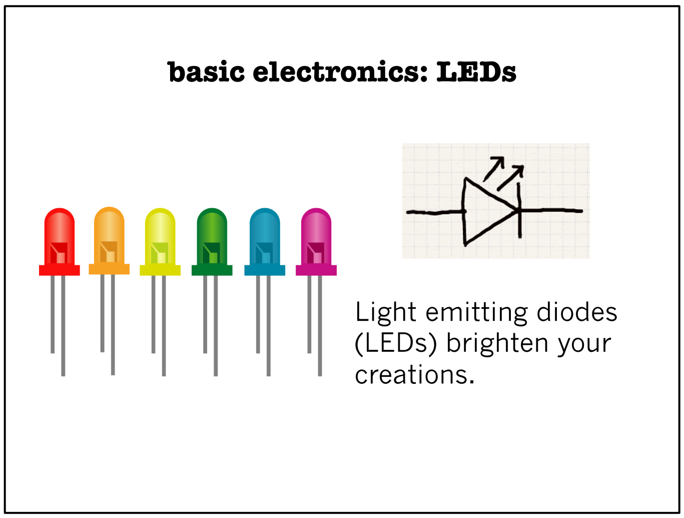


Many musical artists have begun using e-textiles for concerts and red carpet gowns.



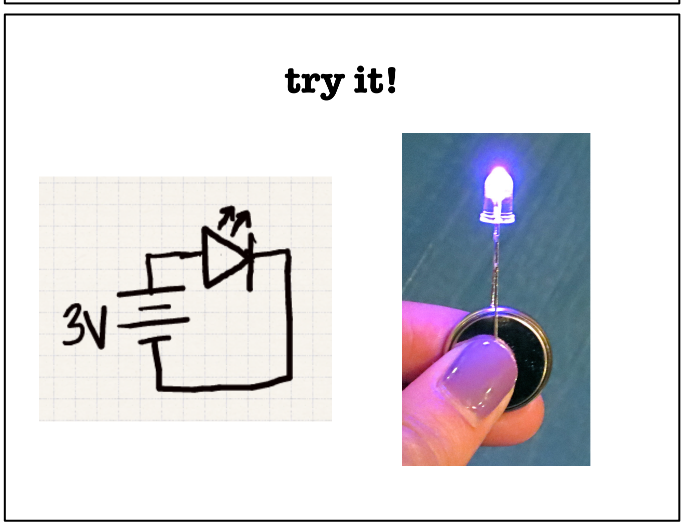
Batteries come in all shapes and sizes. You've probably replaced batteries in video game controllers or TV remotes, or charged batteries in your cell phone or laptop computer. We'll need batteries to power our circuit, and they'll need to be small so we can easily hide them.

Batteries also have different voltages, and the amount of voltage required depends on the circuit. For our project, we'll light up LEDs, which use very small voltages.

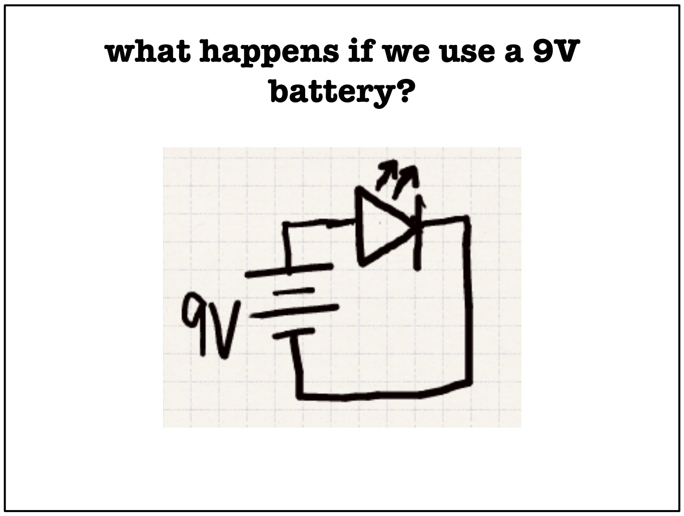


LEDs will be the main component of our circuit. We'll use them to brighten our bracelets.

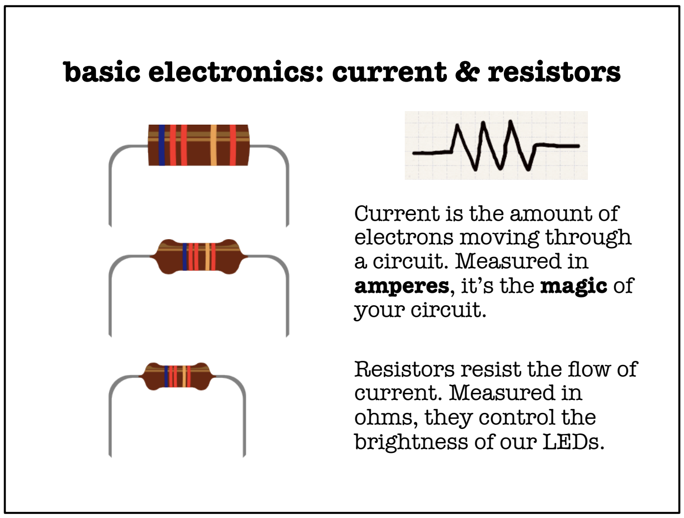
Just like batteries, LEDs have polarity, meaning that electricity only flows in one direction to light the LED. If you look at the part, one lead is longer than the other: the shorter leg is the negative side and the longer is the positive.



Using the coin cell battery (3V), slip the LED leads over the battery, matching positive to negative.

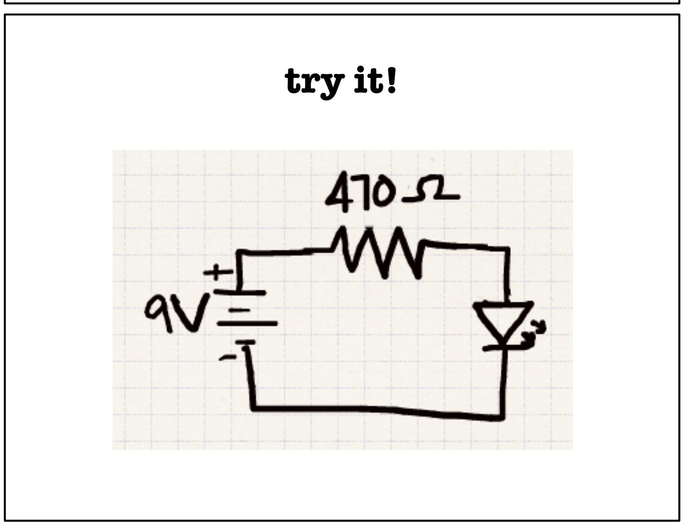


Let's connect the LED to a 9V battery instead and see what happens.
As you see, the LED burns out. That's because the LEDs are only rated for 3V, so we gave our LED too much voltage.



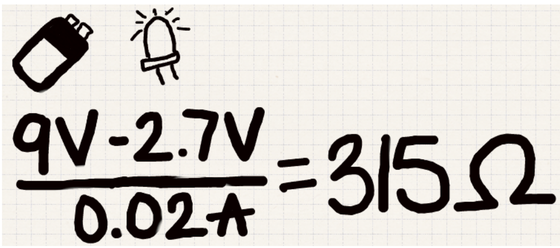
Sometimes, we might want to use a larger voltage supply with our LEDs. More voltage means that we can power more LEDs and that our LEDs will light up for longer. Isn't there a way, then, to protect the LEDs?

Certainly! It's called a resistor. Our LEDs blew up because they sourced too much current, and resistors resist the flow of current.



Use the alligator clips to connect a resistor between the battery and LED. Remember that resistors resist electric current, so the larger the resistor, the dimmer the LED will be. Play with different resistor values to see what happens.

how do you know what LED to use?

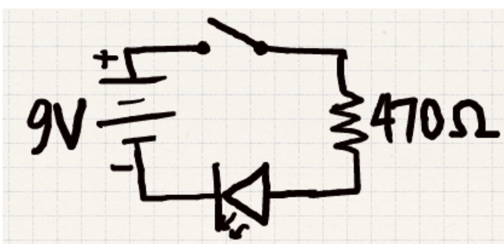


Sometimes, we want our LEDs to shine at their brightest capacity and need to determine the smallest resistor value that won't burn out the LED. How do we do that?

We use math!

All LEDs have what's known as a forward voltage drop and maximum current. In order to calculate the minimum resistor value needed, we subtract the LED's voltage drop from our supply voltage and divide it by the maximum current. For this example, we see its 315 ohms.

basic electronics: switches



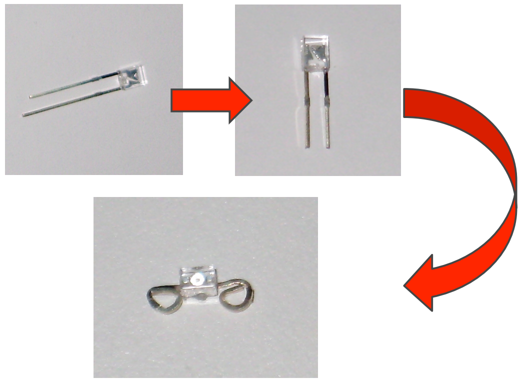
Sometimes, we don't want our LEDs to be on all the time. Think about the lights in your house – would you really want them to be on when you're trying to sleep?

Switches insert a break in an electric circuit; when closed, the positive terminal of the battery is connected to the circuit.

let's make something!

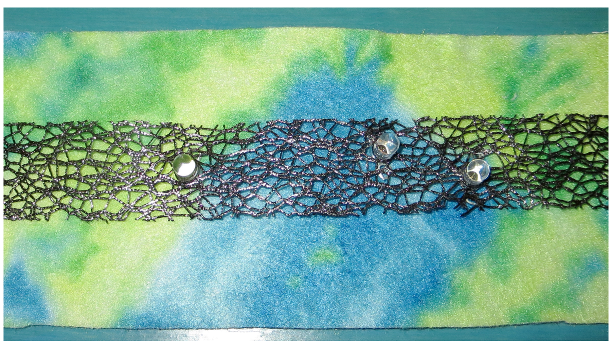
Come up, pick a felt color, choose 3-5 LEDs, and cut a strip of ribbon.

prep LEDs



1. Mark the negative side of your LED with a permanent marker.
2. Trim the LED leads so they're about a half inch long
3. Using pliers, twist the legs so that they form two circles.

position your LEDs



Choose how you want your LEDs to look on your final bracelet by poking the LEDs through the mesh.

Be sure to leave enough room for the battery holder to be connected on one side.

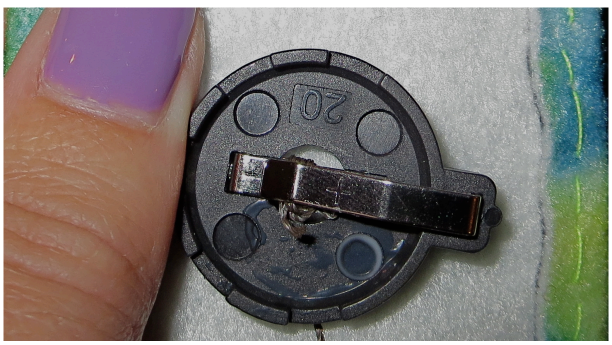
mark position

Use a permanent marker to mark the position of the LEDs.

stitch the LEDs

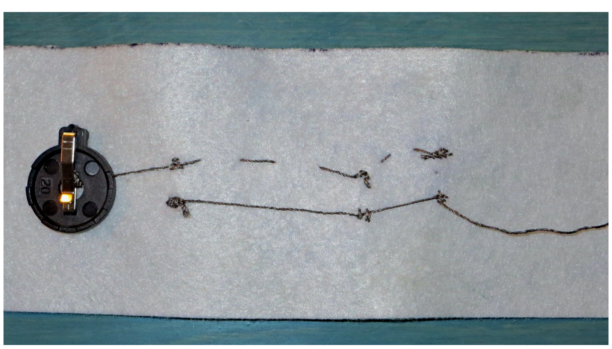
Begin stitching your circuit. Start with the negative terminals of the LEDs and stitch through the LED loop we made 3-4 times. Position the next LED and make a running stitch to its LED loop. This will make sure the threads don't touch when wearing it as a bracelet later. Continue this process for all LEDs.

stitch to battery terminal



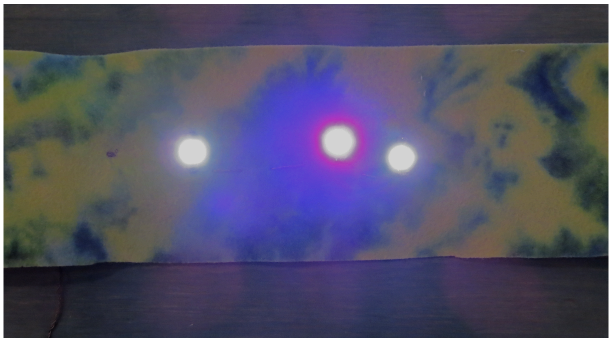
Connect the negative terminals of the battery to the battery holder by sewing around the bottom metal strip.

connect the positive terminals



Stitch the positive battery terminals together, using the same process as before. When done, don't tie off the thread, leave it loose instead.

test your connections



Slide your battery into place, and touch the conductive thread to the positive side of the battery. Your LEDs should light up. If not, check your connections.

stitch to the snaps

Measure the bracelet around your wrist, marking where the snaps should go. Push the snaps through the fabric and stitch around the snap.

Connect one snap to the positive terminal of the battery, and the other to the positive terminal of the LED.

wear it!

Once you're done, connect the snaps and watch the LEDs light up!

Disconnect the LEDs and fit the mesh ribbon back over the bracelet use fabric glue and simple stitches to hold it in place. If desired, hem the edges for a more "polished" look.

Appendix B: Survey Questions

Pre-Workshop Questionnaire

Question	Yes	No	Maybe
I know what an engineer does.			
I have a friend/family member who is an engineer.			
I'm good at math and science.			
I find math and science boring.			
Engineers need to be geniuses.			
Engineers make a lot of money.			
Engineers spend most of their time working in front of computers.			
Engineers aren't very social.			
Engineering make products that help people.			
Engineers aren't creative.			
I want to be an engineer.			

When you think of an engineer, what type of person do you picture?

Would you consider a career in engineering? Why or why not?

What careers are you considering?

Post-Workshop Questionnaire

Question	Yes	No	Maybe
I know what an engineer does.			
I want to learn more about engineering.			
I find math and science boring.			
Engineers need to be geniuses.			
Engineers make a lot of money.			
Engineers spend most of their time working in front of computers.			
Engineers are social.			
Engineering make products that help people.			
Engineers are creative.			
I want to be an engineer.			

What was your favorite part of the workshop?

What was your least favorite part of the workshop?

Would you want to do something like this again?

Based on what you learned today, would you consider a career in a technical field?