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Gender Differences in Reverse Engineering

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Gender Differences in Reverse Engineering

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Dedication

I would like to dedicate this work to my family. They walked by my side through this journey and supported me during these four years. Without their love and support this would not have been possible.

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I would like to thank my husband for his support in getting this master's degree. I am really thankful to Uteach*Engineering* for this opportunity, especially to my supervisor, Jill Marshall, who is one of the most knowledgably mentors that I have ever had.

Abstract

Gender Differences In Reverse Engineering

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The purpose of this study was to investigate possible gender differences related to Reverse Engineering unit of the Engineer Your World curriculum. A pilot study took place in 4 schools in Texas and 1 in Massachusetts. The sample size was 160 students: 121 males and 39 females. Students taking EYW (both as an elective and as a required course) were surveyed about their experiences and interest in reverse engineering before and after the Reverse Engineering unit. Results reported some differences in responses between genders. Females reported a higher curiosity for taking things apart but fewer experiences than the males did, although the difference was not necessary statistically significant. A difference between genders was reported differences in learning about how things that they use on a daily basis (IPhones, digital cameras) work. Despite the students' reported lack of expectation that they would use information learned in the reverse engineering outside of class, they reported an interest in learning more about how things work.

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Chapter 1: Introduction

Our changing world needs creative people who like to solve challenges and make ideas a reality; it needs engineers. Inventors, engineers, and entrepreneurs of the future need fundamental skills in the design process. Engineer Your World (EYW) it is an innovative high school curriculum designed by faculty from the University of Texas at Austin, NASA engineers and secondary teachers. It exposes students to real engineering problems in a project-based environment. More information about the EYW program can be found at their website at: *www.engineeryourworld.org*.

The Reverse Engineering unit is part of the EYW curriculum wherein students learn fundamentals of the engineering design process to redesign a product. They learn that reverse engineering is a systematic process, starting with interviewing customers and analyzing the product then disassembling the product while employing best practices for engineering documentation. Finally all the information is used to collect redesign ideas. My experience of teaching engineering tells me that Reverse Engineering may be an unfamiliar topic for some high school students, especially for girls. Although curriculum developers believe that the Reverse Engineering unit should empower students to study and change the products around them, the teachers implementing the curriculum have observed that is not easy for all students to connect with it. This is not ideal, because in order to keep up with the constantly changing world, we need ideas and solutions for a wide variety of people; we need diversity among engineers.

Nevertheless, gender gaps in STEM-related attitudes (personal, assessments or perceptions of climate) remain strong and constitute a primary reason why women are under-represented in many STEM fields (Riegle-Crumb, 2013, p.2). Research says that some of the less favorable attitudes in girls explain why are they less likely to enter STEM majors in college, yet even among those females who do enter STEM majors attitudes continue to be an obstacle (Riegle-Crumb, 2013, p.2). Consequently we see this discrepancy in the workforce. Women were 50.8% of the population in 2010, but they only made up 13.6% of the employed engineers (2010 census, NCSES). Are curriculum developers doing enough to engage girls in the EYW engineering course? Are they doing enough to promote engineering skills such as the design process among high school girls? Are girls enrolled in the EYW course enjoying the Reverse Engineering unit?

Research says; "The many applications of the expectancy-value model found in the literature offer strong evidence that females exhibit lower self-concept and self-efficacy in their STEM-related abilities and express less enjoyment and value of these fields compared to their male peers" (Riegle-Crumb, 2013, p.2) Although there has been research on gender equity in other STEM (Science, Technology, Engineering and Math) areas, such as gender equity in science classes, it is very limited in engineering classes. Specifically, this study is designed to will try to answer the following questions:

- Do males and females have different experiences and interest in how things work?
- Are there any gender differences in how females and males connected with the EYW reverse engineering unit?

- Is understanding how things work, (reverse engineering) relevant to females and males?

I will provide a brief review relevant literature about Reverse Engineering and women in secondary engineering education in the next chapter.

Chapter 2: Literature Review

It took a while to find the right search terms for my literature research. My first search was done in Google Scholar with the terms: engineering AND secondary education, and engineering AND secondary education AND gender equity. I was able to find about 5 articles that are listed in the references. After Google Scholar, I searched the ERIC database with the terms; secondary education AND engineering, gender equity AND engineering AND secondary education, engineering AND secondary education AND gender differences, and Engineering AND thinking. I was able to find two good articles on gender equity, and a good one about engineering design thinking. All of them are listed in the references. Finally, I did several searches on Education Source and Web of Science with the same search terms: Engineering AND secondary education but was not able to find anything. It was hard for me to find anything related to "reverse engineering." After several searches, I found an article that referred to reverse engineering as "mechanical dissecting," which led me a couple of good articles for my study. Before we proceed into more details about the study and results, I will review findings from the research on reverse engineering, gender equity in engineering, and their connection to this study.

History of Reverse Engineering and its effectiveness in the curriculum

During the 1990's, the National Science Foundation recognized the opportunity to improve engineering education in order to create a learning environment with more

"active learning" and engineering graduates who were thinkers and problem solvers. In order to fulfill this goal (or make an improvement), "mechanical dissection," commonly called reverse engineering, was integrated into the engineering curriculum of major engineering schools (Lamancussa, 1996). Students "dissect" a product or system to determine how it works. "Determining how something works is not stealing someone's ideas, but rather is a beneficial way to enhance the learning process of engineering design for the novice." (Barr, 2013, p.3) According to Professor Richard Crawford, one of the founding faculty members of the EYW curriculum, reverse engineering was included in the curriculum because some of the concepts taught in the unit might be very abstract to novice engineers. He feels there is a need to introduce these concepts early to prospective engineering students (R. Crawford, personal communication). Concepts like costumer needs analysis and functional modeling can seem very abstract for high school students and even for college freshman, but Dr. Crawford found that these strategies are more effective when teaching these concepts with a tangible product.

As previously mentioned, reverse engineering has been a common pedagogical approach as part of the engineering curriculum for over 20 years. (McKenna, Gul & Moore Russo, 2013). Its main purpose was to help students gain an understanding about how things work and to use their intuition and think about the internal components of a product or a system. "Many product dissection activities that are in use today have their roots in Sheppard's (1992) Mechanical Dissection course at Stanford; however, numerous engineering product dissection- based educational activities, course modules,

or entire courses have been developed since then at multiple institutions" (McKenna, Gul & Moore Russo, 2013, p.1). McKenna claims that when the "product dissection" was implemented in some curriculums it tended to focus only on the how the product works and how it is made. He states that this basic approach lacks a global vision for learning about reverse engineering or product dissection. He further claims that curriculum should implement a different approach when including reverse engineering; one such approach is called "product archeology". This approach was initially used by Ulrich and Pearson in 1998 and "it is the process of dissecting and analyzing a physical product to assess the design attributes that drive its cost. More recently, the term has been formally defined as the process of reconstructing the lifecycle of a product—the customer requirements, design specifications, and manufacturing processes used to produce it—to understand the decisions that led to its development" (McKenna, Gul & Moore Russo, 2013, p.2) When students apply the "archeological mindset" to reverse engineering, they are seeking to understand the product and designer global, societal, economic and environmental context and impact. There is reason to believe this approach might be more engaging to females since it requires students to go get a broad idea about the importance of the design process to understand how things work and how that can have a huge impact on society as a whole (National Academy of Engineering Committee on Public Understanding of Engineering, 2008). As stated in ABET guidelines, engineering programs should provide "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context" (McKenna et al., 2013, p.2). An article by Moore-Russo, Cormier Lewis and Devendorf

(2011) addresses the challenge of meeting ABET's outcome about broad education, and those authors implemented the product archeology approach in two engineering courses for their study. The authors did not disaggregate results by gender or ethnicity, but they claimed that the incorporation of product archeology had a positive impact on the students. Unfortunately, there is not any research on what females know about the topic of reverse engineering, nor about the achievement of female students in this area. Now after reviewing the history of the reverse engineering curriculum, I will briefly present relevant results from the literature about females and engineering.

Women and Engineering

Women have made tremendous progress in education and the workplace during the past 50 years, including in scientific and engineering fields. However, women are underrepresented in many science and engineering occupations. For example, women make up more than half of working biological scientists, but they make up less than 7% of mechanical engineers (Hill, 2010). I am a firm believer that in order to support the country's economic growth we need a balanced engineering workforce in which the values and concerns of all the different people, including females, who live in this country are taken into consideration (National Academy of Engineering Committee on Public Understanding of Engineering, 2008; Baker & Leary, 1995). The workforce needs a well-rounded group of engineers. "A steady supply of qualified, creative engineers is key to industry's ability to innovate, and this, in turn, supports overall economic growth. Attracting students from groups that have historically been significantly underrepresented in the engineering profession is especially key" (National Academy of Engineering

Committee in Public Understanding of Engineering, 2008, p.13). Are we doing enough to attract girls into the engineering classes, keep them engaged and most important inspire them to pursue a career in engineering? "Many studies say that many girls reject the physical sciences and engineering because of perceptions that professionals in these areas are not helping or caring and do not address issues related to their concerns" (Chysanthe et al., 2009, p.5). Secondary engineering programs, like Engineering Your World, have the potential to provide the foundation to help alleviate the inequality in the work force. I had the opportunity to teach a couple of these engineering curricula and would like to share some of my experiences.

During the years I was in the classroom, I started to make observations about the connections that girls made on the projects I assigned in my engineering classes. I felt that some girls felt intimidated by the concept of engineering. Consequently, I started posing informal questions to almost all the girls that were enrolled in my class. The most important question was what engineering meant to them. I was shocked when I found that most of them had misconceptions about engineering. Their idea of engineering was "fixing machines and getting your hands dirty." Their main misconception was that they believed that engineering was a "career for men," and that it was about fixing a car and getting dirty. These female students lacked the perspective about the true meaning of engineering and felt intimidated to take the class. Another study that examined gender differences in the Discover Engineering Outreach program found that more girls view engineering as relating to machines, and overall very few students reported engineering as a career of interest to women (Anderson, Gilbride, & Stewart, 2006). But after they

were enrolled as freshman and sophomores, I found that some of these girls started to change their perceptions towards engineering. Some of them even enrolled into after-school engineering clubs like robotics, and were excited to participate and build things with their hands. Several years have passed and some of those students still reach out to me to thank me for inspiring them and encouraging them to pursue a career in engineering. After all, I found that it does make a difference when the girls are exposed to engineering activities and having a role model in the classroom.

The initial misconceptions, however, made recruiting females for the course I taught hard work. In the year that I taught at Idea Public Schools, females in the ninth and tenth grades represented about 55% of the student population, but only 15-20% of the students enrolled in my course were females. The same issue arose in the study of Riegle-Crumb (2013), where 14 % of students enrolled in the EYW engineering high school course, averaged across schools, were female, while females enrolled in each school were half of the student population. How do we attract more females to EYW course? Are we doing enough as curriculum developers to connect with the females enrolled in the course? Is high school too late to try to alleviate gender inequality in enrollment in engineering? The same study found that attitudes and interest are very important factors to take in consideration. According to Riegle-Crumb (2013), the gender gaps in attitudes towards engineering remained "robust" at the end of the year despite the efforts of the curriculum developers to make engineering activities more "appealing" by making the students work in groups learning about their social connections and the improvement of everyday life. "This speaks to the tenacity of attitudes towards and perceptions of STEM

fields, which are constructed and reinforced via the interactions and experiences of females beginning from a very young age" (Riegle-Crumb, 2013, p.62). In order to alleviate some inequality in engineering careers, engineering programs, like Engineer Your World, have been implemented at the high school level in order to expose students to pre-college engineering. "Optimistically, it is possible that such courses could serve a transformative function, bringing large numbers of young females into contact with engineering, dispelling stereotypes about the field, and increasing their interest in the field while bolstering their confidence" (Riegle-Crumb, 2013, p.1). The results from the Riegle-Crumb study showed there is still more work to do and that building a high school engineering course that really works may take several years. Her study was done while the course was still a pilot program and the curriculum needed many revisions. She continues to survey the students and I look forward to see what the new research finds about students' interest and attitudes in engineering.

There has not been any research about the effectiveness of Engineer Your World curriculum in attracting more females into high school engineering classes or inspiring them to pursue a career in engineering. In fact, as noted above, Riegle-Crumb reports that only 14 % of the enrollees in the course were female. There has not been any detailed research about the effectiveness of each particular unit of the Engineering Your World curriculum, nor about females' interest or preference for a specific unit. In regards to attitudes and interests in the EYW curriculum as a whole, Riegle-Crumb reported that female students had lower averages than the male students on personal attitudes scales

measuring their interest in engineering, the intrinsic value they placed on engineering, and their confidence on engineering skills.

The majority of the survey questions for this study measure student interest in the engineering curriculum, more specifically, the Reverse engineering unit. My hypothesis is that females struggle to connect with this unit since the item to be reversed engineered is a flashlight, which is not an item that they use everyday and not an item that makes a huge difference in helping people. Research says that students will be more likely to learn about items they use on a daily basis (Marshall & Berland, 2012). In another study, elementary students were presented several pictures of common items and had to rate their interest in finding our how those items were made. "Girls rated chocolate and ice cream in their top ten whereas boys listed cars and virtual reality games in their top ten. Roller coasters, computers, and cell phones were of interest across genders" (Svihla, Marshall & Petrosino, 2009, p.24). This study also reports that including household items in the curriculum will not necessarily attract more girls into engineering, and that "there are certain technological objects that are of equal interest to girls and boys" (Stwalley, 2007, as cited in Svihla, Marshall & Petrosino, 2009, p.24). A different study, one analyzing engineering activities with 7th graders found that boys reported great enjoyment in the robotics unit, while girls enjoyed the EKG unit best. After examining results, the authors attribute the popularity of the EKG module among females to their persistent interest in human related activities and recommend including those in an engineering curriculum. (Kelly, Klenk, Ybarra, & Cox, 2007). I had similar findings, and I will discuss them in the later sections of the report.

NAECPUEM (2008, p.59), reports "Students are attracted to engineering by the opportunity to both engage their creativity and help people." In regards to helping people, Berland (2013), reported that the EYW class focuses on social relevance, application of engineering in improving everyday life and the use of cooperative and group learning. But I believe there is still some room for improvement in the EYW curriculum and I will discuss more of what I found in this study in later sections of this report. Although the findings for this report might suggest ideas on how to modify the EYW curriculum, more specifically the Reverse Engineering unit, it may be too late to make a change in the females' interest in engineering. As reported by AAUW (2008), attitudes and perceptions towards STEM fields build by interactions and experiences of females at an early age. Another important point to ponder is the prevalence of role models for inspiring and attracting girls into engineering careers. I truly believe that role models play a critical role in inspiring girls to pursue STEM careers, as I have been touched by several throughout my career in engineering and education. Throughout my professional career as an educator, I had the opportunity to serve as a role model for more than 200 female students while teaching at two major public schools in the state of Texas, and was able to witness their growth in regards to perceptions of science and engineering. A study found that "personal contact with a scientist is a major factor affecting science-related career positively affects students attitudes toward scientists and women in science" (Chysanthe et. al 2009, p.5).

After reviewing the most relevant literature about females in engineering education, it is clear to me that there is still a lot to be done regarding gender equity in the

secondary engineering classrooms. Going over the literature and recalling my classroom experiences, I can say that girls are truly interested in human-interest projects that contribute something useful to society. I will present the data collected and analyzed in the next chapter and will provide an overview of how boys and girls connected with the Reverse Engineering unit of the EYW curriculum in Chapter 4.

Chapter 3: Methods

The Surveys

This is study was made using a pre-survey and a post-survey as instruments to learn more about the Reverse Engineering unit in the Engineering Your World high school curriculum. The purpose of the pre-survey was to learn about the experiences and interest of boys vs. girls about how things work. Here the list of questions we used on the pre-survey:

1. Have you ever wondered how a device or machine you use actually works? What was it?
2. Have you ever taken something apart to see how it works inside? What was it? What happened when you took it apart?
3. Has someone (parent, teacher) ever encouraged you to take something apart to see how it works?
4. How much do you agree with the following statements?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Before they design a new product, engineers should take apart or investigate existing products that do a similar thing to see how they work.	☐	☐	☐	☐	☐
Taking apart a hair dryer to see how it works would be interesting.	☐	☐	☐	☐	☐
Taking apart a wall clock to see how it works would be interesting.	☐	☐	☐	☐	☐
Taking apart a flashlight to see how it works would be interesting.	☐	☐	☐	☐	☐
Taking things apart and figuring out how they work would be useful for me in other classes.	☐	☐	☐	☐	☐
Taking things apart and figuring out how they work would be useful for me outside of school.	☐	☐	☐	☐	☐

5. I know and can explain what reverse engineering means.
YES/NO
6. What is your sex?
Male/Female
7. Are you Hispanic or Latino?
YES/NO
8. Please select one of the following choices to best (MARK ALL THAT APPLY)
White/Black/African American/Asian/Native Hawaiian or Pacific Islander/America/Indian or Alaska Native
9. What is the name of your school?

Figure 1: Reverse Engineering pre-survey

The purpose of the post-survey was to learn more about the connections made by boys and girls with the Reverse Engineering unit. Another important item included in the post survey was that whether they were more interested in reverse engineering a different item than a flashlight, for example an item they use on a daily basis (Berland & Marshall, 2012). Here are questions used on the post survey:

1. Are you Hispanic or Latino?
2. Please select one of the following choices to best describe your race (MARK ALL THAT APPLY)
White/Black/African American/Asian/Native Hawaiian or Pacific Islander/American Indian or Alaska Native
3. How much do you agree with the following statements?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I enjoyed working on the Reverse engineering unit.	☐	☐	☐	☐	☐
I would like to learn more about how things work	☐	☐	☐	☐	☐
I enjoyed more working on the Reverse Engineering unit than in Pinhole camera and Data Analysis	☐	☐	☐	☐	☐
Most of the skills learned in the Reverse Engineering unit would be useful to me outside of this class	☐	☐	☐	☐	☐
Reverse engineering plays an important role in solving society's problems	☐	☐	☐	☐	☐
Everything that I learned on the Reverse Engineering unit was meaningful to me.	☐	☐	☐	☐	☐
Reverse Engineering unit has changed the way I think about the functionality of objects	☐	☐	☐	☐	☐
I can apply the skills that I learned on the Reverse Engineering unit outside of class.	☐	☐	☐	☐	☐

4. I know and can explain what reverse engineering means
Yes/no
5. What is your sex? Male/Female
6. What is your school's name?

Figure 2: Reverse Engineering post-survey

As you can see, one item included in both surveys was whether they could explain what reverse engineering was to see if there was an improvement before/after the unit. Consequently I will compare the pre and post results on that item.

The process

Teachers were contacted in October 2013 while the surveys were being developed. The questions were inspired mainly by two publications: Riegle-Crumb (2013) and Berland and Marshall (2012). The surveys were sent to six different schools, five of them in the state of Texas and one of them in the state of Massachusetts. There were a total of 160 students taking the pre-survey, 121 were male and 39 female. On the post survey, there was a total of 155 responses, 119 male and the rest females. The pre-survey was sent in January, 2014, before the students started working on the reverse engineering unit. The post survey was sent in March, 2014. Descriptive statistics were compiled and t-tests were performed to analyze the LIKERT items. Also, I analyzed the qualitative data by coding in order to find word trends, and then a second coder reviewed my data and findings.

Chapter 4: Data Analysis and Results

As stated previously, the purpose of this study was to answer the following questions:

- Do males and females have different experiences and interest in how things work?
- Are there any gender differences in how females and males connected with the EYW reverse engineering unit?
- Is understanding how things work, (reverse engineering) relevant to females and males?

As mentioned in earlier chapters, the study was sent to six schools in the state of Texas and one in the state of Massachusetts, where the EYW was taught for the 2013-2014 academic year. For the pre-survey we included 3 open-ended questions listed below. The sample number was (n=39) for females and (n=121) for males, out of a total of 160 students surveyed. It is important to note that out of those 160 students surveyed, 100 of them are attending a high school where the EYW engineering class is a requirement for all the seniors. This is means that more than half of the answers for this survey come from students who did not choose to take an engineering class, consequently they minimize the sample bias due to self selection. The results for the some of the questions included on the pre-survey are presented below:

Question	Females	Males
Have you ever wondered how a device or machine you use actually works? What was it?	***98%*** have wondered how something works	***93%*** have wondered how something works
Have you ever taken something apart to see how it works inside? What was it?	***77%*** have taken something apart	***83%*** have taken something apart
Has someone (parent, teacher) ever encouraged you to take something apart to see how it works?	***67%*** have been encouraged to take something apart	***56%*** have been encouraged to take something apart

Table 1: Interest and experiences in taking things apart

First of all, I noticed that the percentage of females is a little bit higher than the one presented in the study published by Riegle-Crumb in 2013, where an average of 14 % of students enrolled in the EYW engineering high school course were female. As you can see in Table 1, it is clear that curiosity about taking things apart is very similar among females and males. What really captured my attention is that although the average in interest for genders was very close, the gap from interest to actually taking something apart in females is about a 21% difference. According to Shakeshaft (1995), boys come to school with a greater advantage over girls in the science and engineering classes. They are more likely to have repaired bicycles, played and worked with engines and tinkered with other devices than girls. "These out-of-school experiences provide boys with an added advantage for science learning, giving them familiarity with the physical sciences as conventionally taught in school" (Shakeshaft, 1995, p.75).

It is important to observe that there is 9% difference between females and males, favoring females, in regards to being encouraged by parents or teachers to take something apart, although this difference might not be statistically significant. This stands in

contrast to Shakeshaft's contention that "parents of boys are more likely than parents of girls to buy their sons science toys, send them to science camps or afterschool activities, and subscribe them to science magazines" (Shakeshaft, 1995, p. 75). The Shakeshaft study was done almost 20 years ago, and things might be hopefully changing. Both parents and teachers might have been informed about the gender gap in STEM education and want to encourage girls to participate in STEM-related activities. My hypothesis is that even if females did not get to experience taking things apart, but they were encouraged to take something apart, that could be factor for them in choosing to take the EYW engineering class (or possible a result of it if they were required to take it).

Second, I will present the objects that the students listed when asked which objects they wondered about.

Have wondered how it works	Percentage	
Items	**Female (N=39)**	**Male (N=121)**
Tech personal (*Computers, laptops, cell phones, Ipod, Ipad, video game console etc.*)	*36%*	*55%*
Transportation (*Cars, planes, elevators, bicycles, etc.*)	*13%*	*16%*
Weapon (*guns, rifles, etc.*)	0	*1.6%*
House-hold items (*dryer machine, hairdryer, refrigerator, etc.*)	*13%*	*2.5%*
Control systems (*cruise control*)	*2.5%*	0
Energy generating devices (windmills, solar panels, etc.)	*2.5%*	*1%*
Mechanical devices (*engines, cars, motors, etc.*)	*8%*	*12%*
Tech other (*x-rays, construction lights, laser, motion sensors*)	*7.7%*	0

Table 2: Items listed by males and females.

As you can see from the table above, the most common items mentioned by both males and females were personal technology, including their IPhone, which was the most mentioned item on the survey. As previously noted, research says that students are likely to be interested in items they use on a daily basis (Marshall & Berland, 2012). There is a gap between the percentages of females and males mentioning mechanical devices and personal technology. In a study made of 437 sixth-grade students investigating the differences between boys and girls in regards to science topics, when the students were asked about the things that they would like to learn, it was found that the interest in

learning about planes, cars, computers, light, electricity, radioactivity, new sources of energy, and x-rays was higher in boys than in girls (Jones, Howe & Rua, 1999). In this particular case, a larger percentage of girls reported interest in new sources of energy, whereas as slightly larger percentage of boys reported interest in mechanical and transportation devices, although the difference is not necessarily statistically significant in either case.

Have taken it apart	Percentage	
Items	**Female** *(n=39)*	**Male** *(n=141)*
Tech personal (*Computers, laptops, cellphones, ipod, ipad,video games, rc cars etc.*)	*33%*	*43%*
Transportation (*Cars, planes, elevators, bicycles, etc.*)		*3.5%*
Weapon (*guns, rifles, etc.*)		*2.8%*
School supplies (Pen, pencils, mechanical pencils, etc.)	*23.1%*	*5%*
Musical instruments		*.7%*
House hold items (*dryer machine, hairdryer, refrigerator, etc.*)	*7.7%*	*3.5%*
Mechanical devices (engines, cars, motors, etc.)	*2.6%*	*9.2%*

Table 3: Items taken apart by males and females.

Table 3 represents the items that have been actually taken apart by both males and females. Some females answered that, yes, they had taken apart "things" but did not mention any particular item, and these responses are not included in the table. As you can

see the interest was high in both, but the actual experience of taking something apart is higher in males, although again, possibly not significantly. As noted in the table, females have wondered how something works more than males, but what it is interesting is why their interest is not high enough or it is not a priority for them to actually take the item apart. I question whether they are scared to take it apart or they are just not that interested in doing it. Shakeshaft (1998) stated that girls do more science that they realize, using garden, kitchen and other utensils; they just do not know that they actually doing science. She mentions that " this familiarity with some forms of tools can be used as a way to expand female risk-taking and comfort level with other tools, and help girls understand that the world of science is not as unfamiliar as they might have thought" (Shakeshaft, 1998, p.75).

Furthermore, as noted in Table 1, 67% of female respondents reported being encouraged by a parent or a teacher to take something apart. The fact that these girls are being supported by either a family member or a teacher to take something apart, that is, to engage in reverse engineering in an informal way, is above my expectations. Sherry Turkle, a member of the American Association of University Women's commission on Technology, Gender and Teacher education, found that girls should be encouraged to engage in "tinkering activities" and "artistic play"(Reis & Graham, 2012, p. 15). This publication also mentions that the end of elementary and beginning of middle school is a critical point in girls regarding their mathematical and technological development, so teachers must foster, nurture, and encourage girls during those years (Reis & Graham, 2012). Some of the not-so-promising responses from the surveyed student were: "No they

don't want me to break." "No, I have been discouraged by my parents because they think I'll break whatever it is and it won't work any longer."

For the statistical analysis of the Likert items, a t-test was performed between the two groups, using the null hypothesis (H0) of no gender difference. A scale of (1-5) was used on the Likert questions. Table 4 shows the results for this analysis

Statements	Avg. Female	Avg. Male	P-value
1. Before they design a new product, engineers should take apart or investigate existing products that do a similar thing to see how they work	4.31	4.37	0.66
2. Taking apart a hair dryer to see how it works would be interesting	3.89	3.86	0.81
3. Taking apart a wall clock to see how it works would be interesting	3.92	3.91	0.94
4. Taking things apart and figuring out how they work would be useful for me outside of school	4.13	4.3	0.38
5. Taking things apart and figuring out how they work would be useful for me in other classes	3.62	3.69	0.39
6. Taking apart a flashlight to see how it works would be interesting	3.87	3.74	0.47

Table 4: P-values for Likert items on pre-survey

As you can see, there is a difference in averages between females and males but the difference is not statistically significant. The resulting p-value is obviously larger than the .05 threshold for significance. So I would retain the null hypothesis of no gender difference. The men and women in this study did not exhibit significantly different means on these variables.

Although there is no difference between genders, Table 4 shows an interesting result on question 4, where the average is above 4, which means that students report that what they are learning in their reverse engineering class will be useful to them outside the classroom.

Statements	Avg. Female	Avg. Male	P-value
1. Everything that I learned on the Reverse Engineering unit was meaningful to me	3.36	3.35	0.94
2. I would like to learn more about how things work	4.17	4.28	0.58
3. I enjoyed more working on the Reverse Engineering unit than in Pinhole camera and Data Analysis	2.94	3.12	0.46
4. Reverse engineering plays an important role in solving society problems	3.83	4.14	0.17
5. Most of the skills learned in the Reverse Engineering unit would be useful to me outside of this class	3.64	3.65	0.95
6. I enjoyed working on the Reverse engineering unit	3.72	3.73	0.97
7. Reverse Engineering unit has changed the way I think about the functionality of objects	3.69	3.6	0.65
8. I can apply the skills that I learned on the Reverse Engineering unit outside of class	3.94	3.85	0.64

Table 5: P-values for Likert items on post-survey

As you can see, there is a difference in averages between females and males but again the difference is not statistically significant. The resulting p-value is obviously larger than the .05 threshold typically required for significance. So I would retain the null hypothesis of no gender difference. Men and women do not have significantly different means on these variables. Although the p-values are not statistically significant, question

number 3 captures my attention. The average for the females was 2.94, which means that they did not enjoy working on the reverse engineering unit as much as the previous two. One explanation for this is girls' lack of experiences in taking things apart as noted on Table 1 and in the Shakeshaft article. This lack of experience may cause unfamiliarity with the tools and items used in the unit, and consequently a lack of interest. I also noticed a big difference in the average between males and females on question 4, and consequently a lower p-value, although as noted above, not a reliable indication of a difference between the two groups. Females had a lower average than men in connecting the reverse engineering unit to solving societal problems. This means to me that females did not enjoy this unit much since they did not see the connection to solving societal problems as much as in the other two units. As mentioned in the last chapter and reported by Berland (2013), EYW classes focus on helping society and everyday life through cooperative learning. Given these results, there might be a little room for improvement regarding connecting the work in the unit with societal needs. It is interesting to note that Table 4, statement 4, indicates that the students expect that what they will learn in reverse engineering will be useful outside of the classroom. Unfortunately on Table 5, statement 5 the average for both genders goes down when comparing to statement 4 of the previous table. This means that students expected to learn something useful in the reverse engineering unit, but they lost this connection somehow after completing the reverse engineering unit. This could be possibly linked to the lack of connection to "solving societal problems," as mentioned above.

Lastly, I will present the pre and post averages of agreement with the statement: I know and can explain what reverse engineering is, which was included on both pre and post-survey specifically to probe whether students knew what reverse engineering is.

	Pre-survey		Post-survey	
	Female	Male	Female	Male
I know and can explain what reverse engineering is	72% responded yes	83% responded yes	100% responded yes	93% responded yes

Table 6. Pre and Post data for "I know and can explain what reverse engineering is."

The table above includes the results as percentages. On the pre-test 72% of females responded yes, as well as 83% of the males. I think the results might have been a little different if we had asked the questions at the beginning of the year before the teacher had talked about the class and the different units in it. Comparing the results from those collected on the pre-survey, 100% of females answered "yes" and 93% of the males, which was an improvement of 10% or more for both genders. I also noticed that the difference between pre and post for females is 28%, compared to 10 percent for males. This is means to me that although girls enjoyed more working on the two previous units, they were engaged and actually got the most of the reverse engineering unit.

Chapter 5: Conclusion

Do males and females have different experiences and interest in how things work?

What is data telling us? It is telling us that things are improving slowly and that they look promising but there is still more work to do in regards to gender equity and engineering. It is telling me that the curiosity and interest about how engineering devices work is almost equal across genders, but for some reason when it comes to practice, boys are much more willing to take something apart, to discover, or it may be that boys are just more interested than girls in finding out how an engineering device works.

Research says that girls should be encouraged to engage in "tinkering activities" and "artistic play"(Reis & Graham, 2012, p. 15). Results from this study are saying that females are being encouraged by their parents and teachers to take something apart, to try to understand how that particular device works. For some reason, although females reported high curiosity and interest and are being encouraged, they aren't taking things apart as much as males do. An attempt to try to explain this issue is to look at the things that girls play with and feel comfortable about using. Shakeshaft (1998) stated that girls do more science that they realize, using garden, kitchen and other utensils; they just do not know that they actually doing science. She mentions that " this familiarity with some forms of tools can be used as a way to expand female risk-taking and comfort level with other tools, and help girls understand that the world of science is not as unfamiliar as they might have thought (Shakeshaft, 1998, p.75). A possible way to tackle the problem would be to expose them at an earlier age to get familiar with engineering devices and talking to

them about the connection of science and engineering to the things that they like to do on a daily basis.

It is also important to mention that since boys have demonstrated more experience in regards to taking things apart, this makes them feel more familiar with science and they are more likely to enjoy the learning in the science and engineering classes. As stated by Shakeshaft (1995), p.75, "These out-of-school experiences provide boys with an added advantage for science learning, giving them familiarity with the physical sciences as conventionally taught in school."

Are there any gender differences in how females and males connected with the EYW reverse engineering unit?

Furthermore, when the surveyed students were asked what items have they taken apart, a large number of both males and females mentioned personal technology items like and IPhone a digital camera, etc. As previously stated, the item that they take apart in the EYW reverse engineering is a mini flashlight, but after looking at these results, curriculum developers should consider changing it to something that is more relevant to males and females. Research supports this recommendation and states that students are more likely to be interested in items they use on a daily basis (Marshall & Berland, 2012).

Although no gender difference was found when performing a t-test on the Likert items, there were some answers that really captured my attention. When students were asked to choose a number from a scale from 1-5 for "I enjoyed more working on the Reverse Engineering unit than in the previous two units on the EYW curriculum," the

average for females was found to be 2.94, which is below what was considered neutral. The male average for the same statement was 3.12, which is just slightly above neutral. One explanation for this is girls' lack of experiences in taking things apart as noted on Table 1 and in the Shakeshaft article. This lack of experience may cause unfamiliarity with the tools and items used in the unit, and consequently a lack of interest and not being able to fully enjoy the activities in the reverse engineering unit. Or it might be attributable to the unfamiliarity with the object taken apart (mini flashlight) versus an item they use on a daily basis (IPhone). Another important item to mention was the statement: "Reverse engineering plays an important role in solving societal problems." This statement presented the largest difference in averages between males and females, and consequently the lowest p-value, although as noted in the previous chapter, not a reliable indication of a difference between the two groups. A possible reason that females did not enjoy this unit much is that they did not see the connection to solving societal problems as much as in the other two units. It is interesting to note that Table 4 indicates that the students know that what they learn in reverse engineering will be useful outside of the classroom but do not connect it to solving societal problems. As mentioned in the last chapter and reported by Berland (2013), EYW classes focus on helping society and everyday life through cooperative learning. Given these results, there might be room for improvement regarding connecting the learning on the Reverse Engineering unit with societal needs.

Is understanding how things work, (reverse engineering) relevant to females and males?

I will refer to some of the statements listed In Table 4 and 5 of the previous chapter.

- *Taking things apart and figuring out how they work would be useful for me outside of school.*
- *Most of the skills learned in the Reverse Engineering unit would be useful to me outside of class.*

The averages for females and males on the statements above were: 4.13, 4.3. 3.64, 3.65 respectively, all of which are above neutral. This means that students had high expectations in regards to finding useful information and skills in the Reverse Engineering unit; unfortunately, their expectations went down after they completed the unit. Another important statement to observe was:

- *Everything that I learned in the Reverse Engineering unit was meaningful to me*

The averages for this statement for females and males were 3.36 and 3.35, respectively. Both were slightly above neutral. Fortunately; the averages for both genders in statement 2 look promising. They were 4.17 and 4.28 for females and males respectively. This means that even if they did not find the information on the reverse engineering unit very meaningful, they would to learn more about how things work.

Additional findings and recommendations

After reviewing the data analyzed we can observe some differences between genders and still I find that males have a slight advantage over females in regards to experiences with working and taking apart engineering devices. Although the difference in interests and experiences are not as notable as they were almost twenty years ago as

reported in Shakeshaft (2005), there is still some room for improvement. In order to minimize the gender differences listed above, I would recommend to both parents and educators to start introducing engineering devices to females during as early as when attending elementary school. To support my recommendation, a previous study states that end of elementary and beginning of middle school is a critical point in girls regarding their mathematical and technological development, so teachers must foster, nurture, and encourage girls during those years. (Reis & Graham, 2012).

In regards to EYW curriculum, I would recommend developers considering taking a closer look at the items that their students would like to reverse engineer. If the students are not fully enjoying the reverse engineering unit, it might be worth listening to what they would like to learn about and implement changes in the curriculum as appropriate. Finally, the data also recommends revising the unit in regards to emphasizing the connections of Reverse Engineering to solving problems and its impact on society, since students know the content will help them somehow outside the class, but are not sure how it will help.

Chapter 6: Future Work and Classroom Applications

Future work for this project might involve expanding the number of schools where the survey is being administrated. I would suggest even going out of the EYW network and surveying schools that do not offer engineering classes. I believe that would increase the number of females participating in the study, and would provide a more broader response about gender differences.

On site observations while the students work on the reverse engineering unit and doing personal interviews would enrich the study. I believe talking directly to the students will inform greatly about how engaged they are and how well they connected with the reverse engineering unit. I would also be interested to know about how females became interested in taking the EYW curriculum, what is exciting about taking an engineering class, and investigate in more depth how interested they are in taking things apart and learning about how things work.

For classroom applications, I believe is important to mention that if teachers and educators want to be successful in engaging students in engineering classes, specially when taking gender equity in consideration, they need to consider several aspects and not only about improving the curriculum. As stated by Shakeshaft (1995): “Reform strategies that do not pay attention to the different ways boys and girls think about and participate in science are not likely to succeed. Building confidence, making science familiar and relevant, working with teachers to change attitudes and teaching practices, and helping

girls overcome stereotypes both about scientist and themselves will ensure that “science for all Americans” includes girls” (p.78).

What I would recommend for classroom implementation is to get to know your students, know about their interests and experiences with engineering. I would even ask the research questions used in this study at the beginning of the year. That would give more room to learn about their interests and experiences taking things apart and modify the curriculum accordingly. Also, I would recommend surveying students about their interest to learn more about what they would like to learn in the class. Instructors might also give them a list of items from which they can choose an object to reverse engineer. Finally and most important is that we as educators need to maximize our efforts to connect their classroom learning to societal benefits. As noted in this study, students look for those connections and that is an important factor in how well connect with the class work and how much they enjoy working on it.

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Vita

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This report was typed by the author.