5-2016

Designing Sewn Circuits and STEM Self-Efficacy in Middle School Girls

Kara Kaiser
University of Arkansas, Fayetteville

Designing Sewn Circuits and STEM Self-Efficacy in Middle School Girls

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Human Environmental Sciences

by

Kara Kaiser
University of Arkansas
Bachelor of Science in Education, 2014

May 2016
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

Dr. Glenda Revelle
Thesis Director

Dr. Kathleen R. Smith
Committee Member

Dr. Zola Moon
Committee Member

Abstract

The purpose of this study is to determine if the experience of designing and sewing LilyPad Arduino circuits in crafts projects can increase middle school girls' STEM self-efficacy. Boys STEM self-efficacy will also be assessed to determine if LilyPad Arduino circuits can also increase boys' STEM self-efficacy. Researchers have been wondering why there is a male dominance in STEM (science, technology, engineering and mathematics) fields and why some women do not have a particular interest in these subjects. There are several reasons this could happen; stereotypes conveyed to them by parents and/or teachers, they genuinely are not interested in STEM or their self-efficacy is low in STEM. This study investigated an intervention designed to increase the STEM self-efficacy of middle school girls. A four week workshop was conducted to evaluate whether designing and sewing circuits using the LilyPad Arduino system could in fact help raise middle school girls' STEM self-efficacy. A total of 16 students in 6^{th}-8^{th} grade completed the workshop; 6 girls and 10 boys. After the workshop, data revealed that girls who completed the workshop were more likely to show STEM self-efficacy increases than girls who did not participate in the workshop. However, boys did not see a significant increase or decrease in STEM self-efficacy after completion of the workshop. Self-efficacy is one determinant of how much effort a student will put into an assignment or action, so increased self-efficacy could lead to increased effort in future STEM subjects.

Acknowledgements

Special thanks to my chair and advisor Dr. Glenda Revelle for her help on making this thesis possible from start to finish. Her help has been invaluable in my accomplishments during graduate school. Thank you for your wisdom and guidance during the process of my master's.

Also a special thanks to my committee members Dr. Zola Moon and Dr. Kathy Smith. Both Dr. Moon and Dr. Smith supported and helped pushed me to continue to complete my thesis. I would have been lost without your guidance.

I would also like to thank Mrs. Nancy Simkins and Dr. Laurie Apple. Mrs. Nancy who helped me with each step in my time at graduate school. Dr. Apple who helped with the workshop and encouraged me to keep going along the way.

I would also like acknowledge my friends and fellow graduate students who helped push me to finish. I cannot imagine what these two years of grad school would have looked like without your friendship and support. I consider you guys to be lifelong friends and cannot wait to see what the future has in store for all of us.

Dedication

I want to dedicate this thesis to my parents, Richard and Anne, and my sister and brother-in-law, Sara and Stephen. Without all of your support, prayers, and encouragement I never would have finished my master's. Words cannot express how much I love you guys and appreciate all that you have done for me. Thank you guys for always being there for me and I hope my accomplishment make y'all proud. Love you guys.

Table of Contents

Chapter

CHAPTER 1

Introduction

Researchers have been investigating why there is a male dominance in STEM (science, technology, engineering and mathematics) and why fewer women choose STEM majors and careers. Performance on STEM subjects can be related to girls' self-efficacy and how people have encouraged or discouraged their interest in STEM subjects. In 2011 women only accounted for 26 % of STEM workers while men accounted for 74 % (Landivar, 2013). Even though there has been an increase in females majoring in STEM in the past couple of years, the ratio of females to males remains unbalanced, meaning that there are significantly more males who major in STEM subjects than females (Landivar, 2013). According to Tenenbaum and Leaper (2003), women only represent about one quarter of scientists. Teachers, parents and friends, sometimes without realizing it, can discourage girls from pursuing math and science because of gender stereotypes, since it can be considered a male dominant field. Tenenbaum and Leaper's research showed that "there were not apparent differences between girls and boys in their science-related cognitions or behaviors, there was a strong indication of differential treatment" (p. 42).

Most of society considers STEM to be a masculine domain, and boys tend to take charge when they are present in those classes (Tenenbaum & Leaper, 2003). Tenenbaum & Leaper (2003) go on to suggest that parents' beliefs play an important role when influencing their children's behavior. If parents engage their children in science related activities, this can influence their children's interest in science subjects. Tenenbaum & Leaper (2003) argue that parents believe science is more appropriate for boys than it is for girls. If this statement is true, it could explain why more boys major in STEM subjects than girls. Girls may be told and may observe that they should not major in or take an interest in STEM subjects (Tenenbaum & Leaper, 2003).

When mothers were asked how they thought their daughters compared to boys when it came to science and math performance, mothers believed that their daughters underperformed while they thought their boys overachieved (Tenenbaum & Leaper, 2003). A mother's confidence level can help predict how well the child will perform in the subject. If the mother believes in her child, whether it is a boy or a girl, he or she is more likely to have better success.

Gender-based role assignments are present in every culture and stereotypes tend to come from these culturally assigned roles. In some countries, girls are not able to get an education, while boys are pushed to go to school and succeed in the career world. Society is more likely to encourage boys to pursue STEM subjects and not to encourage girls. Girls can find discouragement when trying to perform in STEM subjects; could it be because their mind works differently, could it be the stereotypes that parents or society has put them on them, or could it be that they do not have an interest in pursuing STEM subjects? There are many variables involved when trying to figure out why there is a male dominance in STEM (Kiran & Sungur, 2012).

Most high schools only require one year of science to graduate, which may be part of the reason there is a deficit in girls pursuing STEM subjects in college after high school (Britner & Pajares, 2006). After the girls have participated in the required number of hours, there is not much incentive for them to pursue subjects from which they are often discouraged. A study performed by the National Educational Longitudinal Study of 1988 reports, "Middle school females have less positive attitudes about science and participate in fewer relevant extracurricular activities than males" (Brickhouse, Lowery, & Schultz, 2000).

Shapiro and Williams believe stereotype threat as “a concern or anxiety that one’s performance or actions can be seen through the lens of a negative stereotype- a concern that disrupts and undermines performance in negatively stereotyped domains” (Shapiro & William, 2012, p. 175). Boys are encouraged to pursue STEM subjects, whereas girls seem to rarely be encouraged to study them. Stereotypes often impact a girl’s view of her ability to perform in a STEM subject. Parents can play a role in stereotyping their children by buying them gendered-stereotyped toys and also encouraging them to pursue gender specific careers in college. A study done by Kiran and Sungur (2012) showed that, “Girls tend to be less self-efficacious in mathematics, physical science and traditionally male-dominated areas, mainly due to the stereotypical beliefs about gender as opposed to gender itself”. Societal norms suggest girls are supposed to be more nurturing than boys and, therefore, are pushed to pursue occupations dealing more with selfless work.

Albert Bandura defines self-efficacy as “people’s beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives” (Bandura, 1993, p. 118). Self-efficacy correlates with confidence levels in a particular task being attempted and determines how people will act and behave. There are four principles that influence self-efficacy: mastery experience, vicarious experiences, verbal persuasion and emotional arousal. These influences contribute to girls’ level of confidence in not only STEM subjects but also other everyday activities and how much effort they will put into a task (Kiran & Sungur, 2012). Science self-efficacy refers to girls’ perceived confidence level in science activities. Researchers believe that increasing a girl’s science self-efficacy will influence her decision about pursuing STEM subjects (Britner & Pajares, 2006). Once girls hit puberty, they lose confidence in their ability in math and science; as a result, they become less interested in math and science (Tenenbaum & Leaper, 2003). Most of society considers STEM to be a masculine domain, and boys tend to take charge when they are present in those classes (Tenenbaum & Leaper, 2003).

Self-efficacy can be diminished in a student who receives negative comments and experiences failure to complete a task. Previous socialization also influences self-efficacy beliefs in one's confidence level for future activities. Self-efficacy does not involve a person's ability to actually perform the task, but instead their perceived abilities (Phan, 2012). For example, if someone's perception of their ability to do math is high, they are going to put more time and effort into working out a problem. If their perception is low, they are more likely to give up working on a problem sooner. Self-efficacy influences people in everyday decisions; for example, which tasks to participate in, how much effort to put into that task, and how long they will spend working on the task (Kiran & Sungur, 2012).

Sahin, Avar and Adiguzel (2014) believed having students participate in STEM activities could help encourage interest in STEM and help provide and interest in reading of STEM subjects. After-school programs are a good way to help increase students’ interest in STEM subjects. The activities performed help students better understand the concepts involved in STEM subjects. After-school programs have led to higher STEM subject grades and also encourage students to work with their peers. By helping facilitate an interest in STEM, the programs become a stimulus for students to pursue STEM careers (Sahin & et al., 2014).

One of the ways we can help girls interested in STEM is through constructionism. Jean Piaget (1962) believed that children gain knowledge through their own experiences and teaching isn’t always direct. Seymour Papert (1980), who was influenced by Piaget, developed the theory of constructionism, in which the learner gains knowledge through hands on experience and inquiry based activities. Teachers are setting up classrooms to help facilitate constructionism by setting up parameters in which children can learn. Children are given the tools to be able to construct knowledge, but how they construct their knowledge is up to the child. Both Piaget and Papert believed children were constructivists: they gain knowledge about their world through personal experiences. Children are allowed to gain knowledge through free learning, there are no parameters set up, more of an informal type of learning. Parents and teachers can scaffold their children into learning more or let them figure it out on their own (Halverson & Sheridan, 2014).

Statement of the Problem

The purpose of this study is to determine if the experience of designing and sewing LilyPad Arduino circuits in crafts projects can increase middle school girls' STEM self-efficacy. In addition the relation between designing and sewing and males STEM self-efficacy will be examined. A new innovation in technology has been wearable computers that sew directly onto a person's clothing using conductive thread ("LilyPad Arduino Main Board," 2015). The LilyPad Arduino circuit is a microcontroller board that was designed specifically to be sewn into fabric. The circuit can be used for fashion by adding an LED light, microphone, or speakers to clothing, and many other functions. The LilyPad Arduino circuit couples STEM with activities thought to be more stereotypical for girls, such as sewing, crafting and fashion. For girls who are not confident in their abilities in STEM, using the LilyPad Arduino circuit has a chance to raise self-efficacy. Self-efficacy is related to the amount of effort a student will put into an assignment or action. Using the LilyPad Arduino circuit could help raise interest in girls, since it may be viewed by the girls to be more of a craft project than a regular circuit board. The LilyPad Arduino circuit is a new and innovative technology that could help break down barriers that are in place when it comes to female participation in STEM.

This study is intended to measure girls' self-efficacy in STEM and examine the hypothesis that the designing and sewing LilyPad Arduino circuits could increase girls' self-efficacy in STEM subjects. The LilyPad Arduino circuit couples STEM with activities thought to be more traditional for girls, such as sewing, crafting and fashion. For girls who are not confident in their abilities in STEM, using the LilyPad Arduino circuit has a chance to raise self-efficacy.

The purpose of this study is to examine the relationship between designing and sewing circuits and females' STEM self-efficacy. Middle school girls who design and sew LilyPad Arduino circuits in crafts projects will be observed.

Hypothesis 1: Girls who engage in designing and sewing circuits will show a greater increase in STEM self-efficacy scores as compared with girls who did not engage in these activities.

In addition the relation between designing and sewing circuits and males' STEM self-efficacy will be examined. Middle school boys who design and sew LilyPad Arduino circuits in crafts projects will be observed.

Hypothesis 2: Boys who engage in designing and sewing circuits will show no greater increases in STEM self-efficacy scores as compared with boys who did not engage in these activities.

Chapter II

Review of Literature

Self-Efficacy

Researchers have been studying the reason for male dominance in STEM (science, technology, engineering and mathematics) and why women have less interest in these subjects than men. There has been a deficit in the number of girls who are interested in STEM, and researchers have been trying to design new ways to encourage girls to be interested. Universities have tried to draw girls into STEM programs, and even certain companies are attempting to only hire women to help with the deficit in STEM.

Bandura defines self-efficacy as "People's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" (Bandura, 1993, p. 118). Self-efficacy may influence girls' activities involving not only school in general but also in STEM subjects. Girls tend to rely on self-efficacy to determine which tasks to participate in and how much effort to exert when involved in STEM activities. If a girl has a low self-efficacy in a STEM subject, she may not put much time or effort into learning.

People tend to base their decisions, such as what classes to take or what major to pursue, on their self-efficacy levels. They may avoid activities they believe they cannot manage. If they take on a project and misjudge what they could handle, their self-efficacy may lower, due to lack of time put into the project or failure to complete it. Self-efficacy influences daily decisions regarding what can be managed by the individual (Bandura, 1982).

Self-efficacy can influence the behavior and motivation level of girls in STEM. If the girl is not confident in a STEM subject, she is more likely to avoid and not attempt to excel in the topic. Bandura (1982) believes people make self-efficacy appraisal about themselves, meaning, when a girl reflects on how she performed on the STEM subject, she may make conclusions on how well or poorly she excelled in the subjects. Girls tend to give themselves either positive or negative appraisals when involving STEM subjects (Bandura, 1982). Self-efficacy can help explain a student's individual learning style and achievement level in different tasks (Phan, 2012). Past experiences and praise help form girls' self-efficacy beliefs in STEM subjects. There are four types of influences on self-efficacy: mastery experiences, vicarious experiences, verbal persuasion and emotional arousal (Kiran & Sungur, 2012).

Influence on self-efficacy. Mastery experience is defined as a "prominent source of efficacy beliefs because it is related to student's interpretations of their past performance" (Kiran & Sungur, 2012, p. 619-620). Mastery experience is especially influential because it is based on past accomplishments. When someone is successful, their mastery experience will increase but when people fail a certain task, their mastery experience will decrease. If people experience repeated failures, not only will their mastery experience go down, but they will also avoid those subjects and tasks (Bandura, 1977). People evaluate the results of their actions to judge their capability to perform the task in the future (Britner & Pajares, 2006).

Vicarious experiences refer to when a person observes someone else perform a certain task. This type of experience is considered less dependable when trying to evaluate one's ability to perform a certain task (Britner & Pajares, 2006). Watching a friend complete a task can be helpful in raising self-efficacy levels in an individual, encouraging someone that he or she can do the same task (Kiran & Sungur, 2012). It can even help someone persist to improve his or her efforts. Being able to watch others can help boost one's self-efficacy by seeing them persist at a task while facing adversities. This demonstrates that the person can accomplish his or her goal with a certain amount of determination (Bandura, 1977).

Verbal persuasion is the positive or negative comments on one's performance of a task, such as from peers, parents or teachers. Weakening self-efficacy through negative appraisals is more prevalent than strengthening self-efficacy with positive appraisals (Britner & Pajares, 2006). This experience is also considered to be an unproductive form of trying to raise self-efficacy. Self-efficacy can be raised and strengthened by a person's own accomplishments, as opposed to receiving compliments from others. Higher levels of efficacy from verbal persuasion can also be diminished by failure of a task (Bandura, 1977). A downfall for verbal persuasion is that confidence does not remain high for long; it has to reoccur from different people to maintain self-efficacy in a person (Kiran & Sungur, 2012).

Emotional arousal is the physiological state while performing a task (Kiran & Sungur, 2012). A stressful situation can diminish self-efficacy while performing a certain task. People tend to avoid situations that induce stress on them. They may start to avoid certain situations so they will not have to deal with the emotions (Bandura, 1977). For example, if a girl has anxiety while taking a test, her self-efficacy and performance level may be lowered (Kiran & Sungur, 2012). When her self-efficacy lowers, she will start to avoid the subject that was giving her anxiety. The girl will assess her confidence level by the emotions she feels while performing the test. Depending on whether the emotions she experiences are negative or positive, there may be a high probability that she will have a low or high self-efficacy for future tests (Bandura, 1977).

Based on the four sources of self-efficacy, past experiences may contribute to a high or low self-efficacy in STEM subjects. There are a number of variables that contribute to how people feel about their self-efficacy. Having a successful experience, does not always mean self-efficacy will rise (Bandura, 1977).

Interest in STEM

Parents and families who encourage STEM learning may ultimately help their child enjoy STEM subjects more. Childhood experiences may be an influential way to help a child take an interest in STEM. Middle school and high school experiences in the classroom also have an influence on children's interest in STEM (VanMeter-Adams, Frankenfeld, Bases, Espina, & Liotta, 2014).

Studies have shown that STEM-related activities have enhanced interest levels in students involved in STEM subjects (Sahin & et. al, 2014). After-school programs are a common way that educators have tried to interest students in learning more about STEM subjects. These after school programs have helped students become more involved in STEM and in interacting with their peers to perform group projects. A common after school activity is Science Olympiad, which is a competition for high school students to compete against their peers from other high schools in STEM subjects (Sahin & et. al, 2014).

Sahin and colleagues have demonstrated that offering after-school programs will help increase an individual's interest in STEM (Sahin & et. al, 2014). With after-school activities, children have time to explore the different aspects of STEM subjects. After-school programs could give students an opportunity to complete more coursework in STEM subjects that they may not be exposed to in the classroom, while also helping students solve problems that are presented in their everyday life. After-school activities provide an environment for students who want to learn more within STEM subjects. These programs help encourage students to share their ideas with their peers and to increase confidence in their knowledge of STEM subjects (Sahin & et. al, 2014). After-school programs are not just intended to help students with their immediate coursework: Research has shown that STEM related after-school programs help increase students' interest in STEM careers (Sahin & et. al, 2014).

Stereotypes in STEM

Gender labels are one of the first labels that children learn. Around eighteen months, children start to understand what gender labels are and to which gender they belong (Bandura & Bussy, 2004). Martin and Ruble (2010) believe "Self-socialization perspectives posit that children actively seek information about what gender means and how it applies to them and that an understanding of gender categories motivates behavior such that, in essence, they socialize themselves" (p. 355). Both girls and boys are trying to understand and conform to the different stereotypes that can be inferred from their culture (Tenenbaum & Leaper, 2003).

Gender roles "as generally expressed in American society, are socially determined activities, attitudes and behaviors based on biological distinctions between sexes" (Marchblank & Letherby, 2014). Society creates the standards on how men and women should act. According to culturally based gender roles, men tend to be more aggressive, while women tend to be nurturing. Children begin to learn their gender roles at birth. Play is also influential on gender roles. Parents of boys tend to buy manly toys such as cars and tools and associate them with the color blue. Parents of girls tend to buy them dolls and house hold toys and associated them with the color pink (Caldera, Huston, & O'Brien, 1989).

A popular hypothesis for why girls do not major in a STEM subject is because of gender stereotypes. Even when kids are young, people have stereotypes that boys and girls should act in a certain way. When raising a boy, parents are more likely to encourage him to pursue a STEM career. When raising a girl, parents typically push them to pursue being a teacher or a stay at home mom. They are encouraged to pursue a more nurturing role in the world. Boys are expected to enjoy and excel in math and science classes while girls are expected to enjoy home economics and fine arts (Kiran & Sungur, 2012).

Girls can find it hard to pursue STEM because for so long it has been considered a male-dominant field (Tenenbaum & Leaper, 2003). Teachers often set up an environment in which girls fail to succeed in STEM subjects. The tendency among educators is to ask girls the easier questions in classroom settings. The boys are then asked the more challenging questions, trying to set them up for futures in STEM subjects (Brickhouse et al., 2000). Because of the influence of society, boys tend to take over in STEM subjects when partnered with a girl. The boys start to believe that they are superior at STEM, and the girls start to believe it as well (Brickhouse et al., 2000).

Parental influence is another factor that plays into girls' self-efficacy in science. Fathers are known to hold their children to stereotypical roles that society has put in place. Fathers were shown to discourage cross-stereotypes in their children in regard to science (Tenenbaum & Leaper, 2003). However mothers can be more influential on children's self-efficacy than fathers (Tenenbaum & Leaper, 2003). A good explanation for this would be that traditionally a lot of mothers have not worked outside the home or only worked part-time and have had more time to spend with their children. Since mothers were around more, they had more of an influence on their children than fathers do. However, as of 2013, 64% of women with a child under the age of 6 were working and the number rises to 75% for women who have children age 6-17 ("Labor Force Participation," 2013). More recently fewer children have their mothers around, in which case the father might be more influential in the child's life than the mother is. As children grow up, however, they are more likely to connect with the same gendered parent, who will have a greater influence on their future (Tenenbaum & Leaper, 2003).

These stereotypes do affect girls' self-efficacy in STEM subjects. Girls' self-efficacy tend to be lower in math, science and other male-dominated areas. Tenebaum & Leaper demonstrate that both self-efficacy and interest help predicts college-aged students selection for majors in science and math (Tenebaum & Leaper, 2003). Self-efficacy has been proven to help determine future careers for both boys and girls. Parents are also a big factor in helping to decide their children's future careers. This could be due to stereotypical beliefs about gender. Girls have a tendency to be more responsible and nurturing than boys, which is demonstrated in many cultures (Kiran & Sungur, 2012).

Career in STEM

Women are the minority when it comes to STEM careers both in the United States and internationally. The deficit is not only a problem in the US but is also a problem every country is facing (Diekman, Brown, Johnston, & Clark, 2010). Girls can find it hard to pursue STEM because for so long it has been considered a male-dominant field (Tenenbaum & Leaper, 2003). To help make girls more comfortable in pursuing STEM as a career, we need to provide them with an optimal learning environment. After school programs can help give girls the push they need to obtain interest in STEM, though researchers must realize that STEM subjects are not for everyone. After school programs can help encourage girls to at least maintain an interest in STEM and help them do better while in school (Sahin et al., 2014).

There are popular and negative stereotypes about girls' abilities in STEM subjects. These stereotypes are conveyed to girls by influential people in their life, e.g. parents, teachers and peers (Shapiro & William, 2012). When high school students were asked what influenced picking their future career, they gave two answers: interest and parents (VanMeter-Adams et al., 2014).

Women tend to be encouraged to pursue careers that allow them to help other people, such as nursing or teaching, because women are stereotyped to be seen as more nurturing and helpful than men. Society has put a stereotype on these types of jobs that they are inherently feminine careers. There are multiple careers that have this stereotype associated with them. Women can sometimes be pushed to fulfill these roles and to leave the other jobs to the men.

Lately, there has been a decrease in the number of people who graduate with a STEM major (Sahin et al., 2014). Because of this lack of interest, the U.S. government has started a program called “Educate to Innovate,” which is aimed at helping students participate in STEM-related subjects to influence them to major in STEM subjects and pursue a career in STEM-related fields (Sahin et. al, 2014). Universities have been doing whatever they can to intrigue more women into majoring in STEM. (Diekman et. al, 2010). VanMeter-Adams et al. (2014) concluded that in the senior year of high school, math and science performance and self-efficacy in these subjects predict whether the student will major in a STEM subject.

Diekman et al. (2010) propose that there are multiple reasons why there is an underrepresentation of females in STEM: differences by self-efficacy levels for gender, cultural stereotypes, and encouragement by others to pursue careers in STEM. Since the 1970s, families have relied on having two incomes instead of one. In the last 40 years, the percentage of women who are working outside of the home has increased from 44% to nearly 60% while men’s percentages have fallen from 79% to 70% (“Facts Over Time,” 2012). Until recently, men have been the sole provider for families; now it takes two incomes to live a comfortable lifestyle. Women have traditionally been told to pursue positions that help people, but now women have more options when it comes to their future careers.

Constructivism, Constructionism, and the Maker Movement

Piaget (1962) believed that children were the active builders of their knowledge. Piaget and Papert (1980) agree that children are the makers of their own cognitive tools; their knowledge of the world is constantly being changed by personal experiences. This theory is known as *constructivism*. Constructivism can be thought as “building knowledge structures” (Papert & Harel, 1991). Children are allowed to gain knowledge through free learning, there are no parameters set up, more of an informal type of learning that they gain through personal experiences.

Seymour Papert first developed the theory of *constructionism* in the 1980s, which was derived from Piaget’s theory. Constructionism can be thought as “learning by making” (Papert & Harel, 1991). Papert believe that children construct knowledge by actively engaging in their world, and that children learn from hands on experience with their surroundings (Halverson & Sheridan, 2014). Teachers are setting up classrooms to help facilitate constructionism by setting up parameters in which children can learn. Children are given the tools to be able to construct knowledge, but how they construct their knowledge is up to the child. Papert believes that projecting our feelings and expressing ideas are key to learning. He emphasized self-directed learning, which is when people create the tools to help explore what is close to their heart (Papert & Harel, 1991).

In the twentieth century, people tended to make or fix their own things, such as sewing their own clothes. For the past couple of decades, there has been a shift to creating via the computer. Lately there has been an interest in people constructing and sharing their own personal creations; this has been deemed the “maker movement.” People are becoming the producers instead of the consumers (Halverson & Sheridan, 2014).

Recently, there has been research conducted on engaging students in problem-based learning and learning through computer technology (Halverson & Sheridan, 2014). Constructionism has been practiced in schools and by multiple educators to help increase knowledge. Teachers are going back to children making and constructing as learning in the classroom. Teachers are tying the maker movement with technology (Halverson & Sheridan, 2014).

LilyPad Arduino

Recently, there have been more tools available for circuitry that use non-traditional conductive materials, such as e-textiles. Electronic textiles, or e-textiles, are part of the "maker movement" in which people are able to learn how media is made and designed on their own, which uses both electronics and computing (Kafai, Fields, & Searle, 2014). The LilyPad Arduino circuit uses conductive material to conduct energy through fabric. These new conductive materials have helped pave the way for inserting computers into wearable fashion. Fashion is a domain that appeals primarily to women, and the LilyPad Arduino circuit has potential to help girls become more interested in STEM subjects. It is also an affordable way for people to learn more about circuits and to be able to do it themselves (Kafai et al., 2014). Kafai et al. believe that e-textiles can provide an opportunity for girls to explore an area that is considered masculine; combining engineering with feminine technologies of crafting and sewing (2014).

The LilyPad Arduino is defined as "A microcontroller board designed for wearables and e-textiles" ("LilyPad Arduino Main Board," 2015). It can be sewn onto almost any type of fabric using conductive thread (Peppler & Glosson, 2013). The LilyPad Arduino circuit was created not only for girls, but also for anyone to investigate structures used in circuitry. Stitches in the LilyPad Arduino circuit will reveal the structures in the circuit and can be observed by the student. The LilyPad Arduino circuit allows people to look at the structures that make up the innerworking of a circuit.

The LilyPad Arduino circuit could be a tool to help girls increase their interest and confidence level in STEM. Sewing, crafting and fashion are activities and hobbies that many girls enjoy. Even though boys can work with the LilyPad Arduino circuit, it does not necessarily entice them to work more with circuits, since in general boys have typically been more interested in traditional circuitry than girls have. The LilyPad Arduino circuit is not meant to force every girl into liking STEM, but rather provide a helpful way to discover if they have an interest or to encourage interest. The circuit uses components of engineering and computing by using sensors that measure different elements, such as light or temperature that are sewn on clothing by using conductive thread and is attached to a small sewable computer that people can program themselves (Kafai et al., 2014).

The goal of this study is to use the LilyPad Arduino circuit to engage girls in STEM activities with the potential to help raise self-efficacy levels. The LilyPad Arduino circuit can be considered a gender-acceptable device that could help women become more interested in STEM. The LilyPad Arduino circuit is a part of the “maker movement” and encourages girls to construct their own circuit to help increase their knowledge in electronics (Halverson & Sheridan, 2014), interest in STEM and help raise self-efficacy levels.

Chapter III

Method

Research has shown that middle school is a critical period for keeping girls' interest in STEM subjects (Uttal & Cohen, 2012). There is a deficit of girls pursing STEM careers after college and there is very limited representation of girls out in the career world. In 2011 women only accounted for 26 percent of STEM workers while men accounted for 74 percent (Landivar, 2013). Even though there has been an increase in females majoring in STEM, the ratio of females to males remains unbalanced, meaning that there are significantly more males who major in STEM subjects than females (Landivar, 2013). The primary goal of this study is to determine if the experience of designing and sewing LilyPad Arduino circuits in crafts projects can increase middle school girls' STEM self-efficacy.

A new innovation in technology has been wearable computers that sew directly on to a person's clothing using conductive thread called LilyPad Arduino ("LilyPad Arduino Main Board," 2015). The LilyPad Arduino circuit is a microcontroller board that is aimed specifically for girls. The circuit can be used for fashion by adding on LED light, microphone, speakers to clothing, and many other functions.

Participants

Participants in this study were students at two middle schools in rural areas in the South. IRB approval was obtained (See Approval Letter in Appendix F) and an informed consent letter was distributed and consent from both the child and the parent was obtained (See IRB Protocol with Consent Letter and Form in Appendix E).

The sample for the intervention group in the study was composed of 21 students from a rural middle school. The students' were in grades 6^{th}-8^{th}. These students completed a pre- and post-test STEM self-efficacy survey and engaged in a four-week STEM workshop for an hour a day after school. Ten males and 11 females began the four-week STEM workshop: 10 males and 6 females completed the STEM workshop. The primary reason for high dropout rate among females was conflict with other after-school activities, such as cheerleading.

The control group for the study was composed of 20 students from another rural middle school in Northwest Arkansas. Ten males and 10 females completed the pre- and post- STEM self-efficacy survey on approximately the same dates as the intervention group, with no intervening contact with the research project.

At the same school as the intervention group, a group of randomly selected students who did not participate in the STEM workshop were asked to fill out the STEM self-efficacy survey once to serve as a baseline for comparison with the STEM self-efficacy pre-test scores of students who chose to participate in the STEM workshop. Ten girls and 7 boys filled out the STEM self-efficacy survey one time during the workshop. This was to address the question of whether any differences in pretest scores might be attributable to self-selection for the workshop versus differences in STEM curriculum teaching across the two schools used in the study. Pre-test data was also gathered from a group of students in the same school as the intervention group.

Instruments

The pre- and post-test used to evaluate STEM self-efficacy in the study was developed by S. Velayutham, Aldridge, and Fraser (2011) (See Appendix A). The study used Trochim and Donnely's framework for construct validity to guide their questionnaire. Cronbach alpha coefficient was .90, indicating internal consistency reliability and validity. The survey consisted of eight questions which were used to obtain data on science self-efficacy in middle school girls and boys. Both the experimental and control groups completed the pre and post survey. Students indicated how they would describe themselves as a student in science by circling one of the answer choices given on a 5 point Likert scale. The Likert scale included the following answers: Strongly Disagree (1), Disagree (2), Not Sure (3), Agree (4), and Strongly Agree (5).

Workshop

The students in the STEM workshop met for one hour every day after school for four weeks. Over the course of the four weeks, the students worked on four projects: a bookmark, a keychain, a baseball cap, and a t-shirt. Before each project began, researchers led a circuitry lesson related to that project. The bookmark involved a simple circuit with one LED; the keychain utilized a parallel circuit, with two LEDs; the baseball cap included use of the LilyTwinkle computer chip with four LEDs; and the t-shirt involved use of the LilyTiny computer chip with eight LEDs. The LilyTwinkle and LilyTiny chips are pre-programmed to flash the LED lights in different patterns. This workshop did not include children doing their own programming, but scaffolded the sequential difficulty of the circuitry involved in creating the four projects.

Bookmark. Each child had an option to decide between two different patterns; a ladybug or a stars and moon design (See Figure 6 in Appendix D). Each participant was provided with a starter kit that consisted of cut-out felt pieces needed for the pattern, and a pre-threaded needle with pre-knotted thread. Researchers gave a lesson on creating a simple circuit, and students were asked to design the circuit for the bookmark project on paper (See Appendix B Section I). The students first drew the connections on the template (See Figure A in Appendix C) provided using a red pencil to outline the positive circuit pathway from positive on the battery pack holder to positive on the LED light and a black pencil to outline the negative circuit pathway from the negative on the LED light back to negative on battery pack holder. Then they practiced sewing the circuit lines onto the paper drawing before beginning to sew on the felt for the bookmark. Next they secured the positive side of the battery holder to the felt for the bookmark using conductive thread, and sewed a path to the positive side of the LED. Similarly, they sewed a second path to connect the battery holder's negative side to the LED. Students were required to get approval from one of the researchers before inserting a battery to test the circuit. Once the circuit was complete, students glued felt pieces to the bookmark to complete the design.

Keychain. Patterns for the keychain were created ahead of time and the students had the option of choosing to make a monkey or cardinal, their school mascot (See Figure 7 in Appendix D). Felt pieces were once again cut out for the students in advance, and needles were pre-threaded, but students were given the opportunity to start learning how to tie their own knots in the thread. In addition, each child was given two LED lights for use in the keychain. Researchers gave a lesson on creating a parallel circuit, and students were asked to design the circuit for the keychain on a piece of paper (See Appendix B Section II). The students drew the circuit connections on a template (See Figure 3 in Appendix C) using a black pencil to outline the negative pathways and a red pencil to outline the positive pathways creating a parallel circuit from the battery pack holder to both LED lights. Then they practiced sewing those lines onto the paper drawing before beginning sewing the felt for the keychain. Next they secured the positive side of the battery pack holder to the felt for the keychain using conductive thread, and sewed paths to the positive sides of each of the two LEDs. Similarly, they sewed paths to connect the battery holder's negative side to the two LEDs negatives. Students were required to get approval from one of the researchers before inserting a battery to test the circuit. Once the circuit was complete, students glued felt pieces to the keychain to complete the design.

Ball Cap. The students had two options for the ball cap; cardinal or free-form design (See Figure 8 in Appendix D). The cardinal had pre-cut felt pieces available for students to use, but if they chose to do a free-form design, they cut out their own felt pieces or used felt stickers. By this point, most of the students knew how to thread needles and tie knots in their thread. The students were given four LED lights and a LilyTwinkle, which makes the lights twinkle-fade in a random pattern. Researchers gave a lesson on creating a parallel circuit using a LilyTwinkle, and students were asked to design the circuit for the ball cap on a piece of paper (See Appendix B Section III). Before they started sewing, the students first drew the connections on the template (See Figure 4in Appendix C) using a black pencil to outline the negative circuit pathways in parallel circuits from the battery pack holder to the LED lights and a red pencil to outline the positive pathway and parallel circuits from the battery pack holder to LED lights and LilyTwinkle. Students then sewed a connection between the positive tab on the battery pack to the tab on the LilyTwinkle and sewed connection from the LilyTwinkle to the LEDs. Students were required to get approval from one of the researchers before inserting a battery to test the circuit. Once the circuit was complete, students glued the felt pieces to the baseball cap to complete the design.

T-Shirt. For the fourth project the students worked on a t-shirt (See Figure 9 in Appendix D). The students created their own designs and cut out felt pieces on their own or used felt stickers. By this point, most of the students knew how to thread needles and tie knots, with just a few requiring assistance. Researchers gave a lesson on creating a parallel circuit using a LilyTiny, and students were asked to design the circuit for the t-shirt on a piece of paper (See Figure 1 in Appendix B). Before they started sewing, they were given a template (See Figure 5 in Appendix C) of the shirt and were required to create a plan for the circuitry to connect eight LED lights and a LilyTiny. The students first drew the connections onto the template, using a black pencil to outline the negative pathways for parallel circuits from the battery pack holder to the LED lights, and a red pencil to outline the positive pathways for parallel circuits from the battery pack holder to LilyTiny and the LED lights. The LilyTiny has four different options for making the lights light up: number zero created a breathing fade, number one flashes in a heartbeat pattern, number two blinks on and off, and number three provides a random fade. The students could choose one or more of these options to use in their circuit design. Students sewed connections from the positive tab on the battery pack to the positive tab on the LilyTiny and from the LilyTiny to the LED lights using parallel circuits. Connections were sewn from the negative tab on the battery pack to the LED lights from the LilyTiny using parallel circuits. Students were required to get approval from one of the researchers before inserting a battery to test the circuit. Once the circuit was complete, students glued felt pieces to the t-shirt to complete the design.

Chapter IV

Results

The primary goal of this study is to determine if the experience of designing and sewing LilyPad Arduino circuits in crafts projects can increase middle school girls' STEM self-efficacy. A STEM self-efficacy survey was used to assess student's self-efficacy in STEM subjects in both boys and girls.

Participant Data

A total of fifty-two boys and girls who were in the 6th, 7th, and 8th grade from two rural middle schools in the South were asked to fill out a STEM self-efficacy survey (see Appendix A). As seen in Table 1, fifteen students completed a STEM workshop that met every day after school for one hours for four weeks (6 girls and 10 boys). Seventeen students from the same middle school completed the STEM self-efficacy survey once to serve as a baseline comparison with students who chose to participate in the STEM workshop (10 girls and 7 boys). Twenty students (10 girls and 10 boys) from a different rural middle school in the same region of the South served as a control group and completed pre- and post-STEM self-efficacy surveys only. Participation for both the STEM workshop and filling out the STEM self-efficacy survey was voluntary and students could drop out at any point. The data analysis was designed to determine whether changes in STEM self-efficacy from the pre-test to the post-test were significantly different for students who completed the STEM workshop versus the control group.

Table 1

Participation Data for Girls and Boys

Participation	Frequency
Workshop Participants	
Male	
6th	7
7th	3
8th	0
Total	10
Female	
6th	3
7th	1
8th	2
Total	6
Total Workshop Participants	16
Control Participants	
Male	
6th	7
7th	3
8th	0
Total	10
Female	
6th	6
7th	4
8th	0
Total	10
Total Control Participants	20
Baseline Participants	
Male	
6th	2
7th	0
8th	5
Total	7
Female	
6th	5
7th	0
8th	5
Total	10
Total Baseline Participants	17
Total Males	26
Total Females	26
Total Participants	52

Data Analysis: Females

The first hypothesis stated: girls who engage in designing and sewing circuits will show a greater increase in STEM self-efficacy scores as compared with girls who did not engage in these activities. A two-way (Treatment x Time of Test) analysis of variance was conducted to examine the effects of participating in a STEM workshop on girls' STEM self-efficacy (see Table 2 for descriptive statistics).

Girls who participated in the STEM workshop showed a somewhat higher STEM self-efficacy overall (M = 4.42) than girls in the control group (M = 4.12). This effect is marginally significant $F(1,14) = 2.96$, $p = .11$. With regard to the interaction of treatment versus-time of test, although there was an increase in scores for the experimental group and there was no increase for the control group, this effect was not statistically significant $F(1,14) = 1.695$, $p = .21$.

Table 2

Descriptive Statistics for Girls Experimental and Control Group

Treatment		Mean	Std. Deviation	N
Experimental	Pretest	4.32	.433	6
	Posttest	4.52	.382	6
	Overall	4.42	.407	6
Control	Pretest	4.14	.259	10
	Posttest	4.09	.474	10
	Overall	4.12	.300	10

Since there were no significant results in the ANOVA test, a Chi-Square test was performed to determine if a significantly greater number of girls in the experimental group showed an increase in STEM self-efficacy than the number of girls who showed an increase in the control group (see data in Table 3). Since three of the expected cell frequencies were less than five, the Fisher's Exact Test was performed. Results indicated that the number of girls in the experimental group who showed an increase was significantly greater than those who showed an increase in the control group one-sided $p = .026$, Fisher's Exact Test. The results from the Chi-Square support the hypothesis that girl's participation in the STEM workshop would lead to increases in STEM self-efficacy.

Table 3

Chi-Square Data for Girls Experimental and Control Group

	Increase	No Increase
Experimental	6	0
Control	4	6

As reported in the previous section, girls in the experimental group had a higher STEM self-efficacy scores overall (pre and post) than girls in the control group. Since the control group students were in a different school from the students who participated in the STEM workshop, a question was raised as to whether the differential school experience was responsible for this difference in STEM self-efficacy. Alternatively, there may have been a "self-selection" factor, in which girls who had a higher STEM self-efficacy to begin with chose to participate in the STEM workshop. To address this question, 10 girls were chosen at random from the same grades in the same school where the STEM workshop was conducted, and asked to fill out a STEM self-efficacy survey to serve as a baseline measure for comparison. An analysis of variance was conducted to examine whether the girls who chose to do the STEM workshop had a higher STEM self-efficacy than other girls within the school (see data in Table 4). A one-way ANOVA examined potential differences between the experimental workshop girls and baseline group for the STEM self-efficacy survey pretest.

Although, girls who participated in the STEM workshop showed a somewhat higher STEM self-efficacy (*M* = 4.32) than the girls in the baseline group (*M* = 3.97), this difference was not statistically significant F(1,15) = 1.413, $p = .25$.

Table 4

Descriptive Statistics for Baseline and Experimental Workshop

Treatment	Mean	Std. Deviation	N
Baseline	3.97	.62	10
Experimental Workshop	4.32	.43	6

Data Analysis: Males

The second hypothesis stated: Boys who engage in designing and sewing circuits will show no greater increases in STEM self-efficacy scores as compared with boys who did not engage in these activities. An analysis of variance was conducted to examine the effects of participating in a STEM workshop on boy's STEM self-efficacy (see Table 6 for descriptive statistics). A two-way ANOVA test was conducted between the experimental and control group for pre- and post- STEM self-efficacy.

Boys who participated in the STEM workshop showed significantly higher STEM self-efficacy scores overall (*M* = 4.73) than the control group (*M* = 3.68), F(1,17) = 29.76, $p < .001$. Although scores increased slightly for the experimental group and decreased slightly for the control group, this interaction effect was not statistically significant F(1,17) = 2.22, $p = .16$.

Table 6

Descriptive Statistics for Boys Experimental and Control Group

Treatment		Mean	Std. Deviation	N
Experimental	Pretest	4.70	.272	10
	Posttest	4.78	.357	10
	Overall	4.73	.295	10
Control	Pretest	3.73	.552	10
	Posttest	3.63	.509	10
	Overall	3.68	.502	10

Since there was no significant interaction effect in the ANOVA test, a Chi-Square was performed to determine if a significantly greater number of boys in the experimental group showed an increase in STEM self-efficacy than the number of boys who showed an increase in the control group (see data in table 7). Since two of the expected cell frequencies were less than five, the Fisher's Exact Test was performed. Results indicated that there was no significant difference in the number of boys in the experimental group versus the control group who showed an increase, one-sided p = .500, Fisher's Exact Test. The results from the Chi-Square support the hypothesis that boys' participation in the STEM workshop would not lead to increased STEM self-efficacy.

Table 7

Chi-Square Data for Boys Experimental and Control Group

	Increase	No Increase
Experimental	5	5
Control	4	6

To evaluate whether the boys who chose to participate in the STEM workshop had a higher than average self-efficacy in STEM before beginning the workshop, seven boys were chosen at random from the same grades in the same school where the STEM workshop was conducted, to fill out a STEM self-efficacy survey. An analysis of variance was conducted to examine whether the boys who chose to participate in the STEM workshop had a higher STEM self-efficacy than other boys within the school (see data in Table 8). A one-way ANOVA test was conducted using the pretest scores of the boys in the workshop and one-time scores for the baseline group.

Boys who participated in the STEM workshop showed a higher pretest STEM self-efficacy (*M* = 4.69) than boys in the baseline group (*M* = 4.29). The analysis of variance showed that this difference was statistically significant, $F(1,16) = 4.784$, $p = .045$.

Table 8

Descriptive Statistics for Baseline and Experimental Group

Treatment	Mean	Std. Deviation	N
Baseline	4.29	.19	7
Workshop	4.69	.26	10

Data Analysis: Males versus Females

A two-way analysis of variance was conducted to examine whether the boys who chose to participate in the workshop group had a higher STEM self-efficacy than the girls who decided to participate in the workshop group (see data in Table 9).

Boys who participated in the STEM workshop showed a somewhat higher STEM self-efficacy overall (*M* = 4.73) than girls in the workshop (*M* = 4.42). The analysis of variance showed this difference was not statistically significant, $F(1,15) = 3.069$, $p = .102$.

Table 9

Descriptive Statistics for Boys and Girls Experimental Group

Treatment		Mean	Std. Deviation	N
Male Experimental	Pretest	4.69	.257	10
	Posttest	4.78	.357	9
	Overall	4.73	.295	10
Female Experimental	Pretest	4.32	.433	6
	Posttest	4.52	.382	6
	Overall	4.42	.407	6

To evaluate whether the boys who were randomly chosen to participate as a baseline group had a higher STEM self-efficacy than the girls who were randomly chosen to serve as a baseline group. An analysis of variance was conducted to examine whether the boys in the baseline group had a higher STEM self-efficacy than the girls in the baseline group (see data in Table 10). A one-way ANOVA test was conducted using the pretest scores of the boys and the girls in the baseline group.

Boys in the baseline group showed a higher STEM self-efficacy (M = 4.29) than the girls in the baseline group (M = 3.97). The analysis of variance showed that this difference was not statistically significant, F(1,16) = 1.245, p = .282.

Table 10

Descriptive Statistics for Baseline Boys and Girls

Treatment		Mean	Std. Deviation	N
Male Baseline	Overall	4.29	.497	7
Female Baseline	Overall	3.97	.620	10

Chapter V

Discussion and Conclusion

The purpose of this study was to determine whether the experience of designing and sewing LilyPad Arduino circuits in crafts projects can increase middle school girls' STEM self-efficacy. The study also looked at boys' STEM self-efficacy, and whether participating in the workshop helped increase their STEM self-efficacy. Men have a dominant presence in the STEM world and researchers have been trying to figure out why. A STEM self-efficacy survey was used to assess students' self-efficacy in STEM subjects in both boys and girls before and after the STEM workshop.

Discussion

The results from this study are in line with the hypotheses proposed in the introduction of this paper. More of the girls who participated in the STEM workshop showed an increase in STEM self-efficacy than the girls who did not participate in the STEM workshop. Boys who participated in the STEM workshop did not see a significant increase or decrease in STEM self-efficacy. These results open the door for the possibility that engaging in activities using the LilyPad Arduino system may help raise STEM self-efficacy by appealing to traditionally female domains.

The first hypothesis in the study stated that girls who engage in designing and sewing circuits will show a greater increase in STEM self-efficacy scores as compared with girls who did not engage in these activities. Girls who participated in the STEM workshop showed an increase in STEM self-efficacy. However, even though there was an increase in levels of STEM self-efficacy, the difference in the amount of increase for girls participating in the STEM workshop versus the control group was not statistically significant. Non-parametric tests, however, showed that girls who participated in the workshop were more likely to show an increase in self-efficacy after completion of the workshop than girls in the control group.

When looking at the data comparing girls in the workshop to the baseline of girls from the same school, girls who participated in the STEM workshop showed a slightly higher STEM self-efficacy. However, this difference was not statistically significant. This comparison was made to see whether there was a self-selection process in which the girls who choose to participate in the STEM workshop had a higher STEM self-efficacy even before the STEM workshop started. Since the study involved voluntary participation, it seems logical to assume that girls who already have a higher interest in STEM might be more likely to choose to participate in the STEM workshop.

One of the possible reasons for the girls' who participated in the STEM workshop not showing a greater increase in STEM self-efficacy could be that they already started off with a high STEM self-efficacy. Their score was close to the ceiling number, which is 5. There was not much room for them to gain a higher STEM self-efficacy.

When the STEM workshop started, eleven girls had signed up to participate. As the days went on, girls started to drop out from the STEM workshop. Conflicting after school activities, such as cheerleading, was one of the reasons some of them had to drop. Once the STEM workshop was completed, only 6 girls were left.

The second hypothesis in this study stated that the boys' self-efficacy levels would not increase after participation in the workshop and would not differ from the control group. Boys who participated in the STEM workshop saw no significant increase or decrease in STEM self-efficacy after participation. It is possible that we did not see a significant increase in the boys because they were already very close to the ceiling number. Before the STEM workshop the boys' mean STEM self-efficacy score was already 4.70, so there is not much room to improve, as the highest number possible is 5. Boys who participated in the control group also showed no increase or decrease in STEM self-efficacy for both pre- and post-test. However, boys who did participate in the STEM workshop showed significantly higher STEM self-efficacy scores overall than the control group.

When looking at the data comparing boys in the workshop to the baseline of boys from the same school, boys who participated in the workshop showed a significantly higher self-efficacy than the boys who were randomly picked from the same school. This shows that there was a self-selection factor for boys who choose to participate in the STEM workshop. Boys who felt more competent in their abilities in STEM were the ones who signed up to participate in the workshop.

Looking at the data for both boys and girls who participated in the workshop, boys showed a slightly higher self-efficacy than the girls. However, the difference was not statistically significant. This comparison was made to see whether the boys who participated in the workshop had a higher STEM self-efficacy than the girls who participated. The data comparing both boys and girls who were randomly chosen to participate in the baseline group, showed that these boys also had a slightly higher self-efficacy than the girls; however, the difference was not statistically significant. The comparison was made to see whether the boys who were randomly chosen to take the STEM self-efficacy survey had a higher STEM self-efficacy than the girls who were randomly chosen.

When the workshop started, ten boys participated in the workshop. Unlike the girls, all ten boys saw the workshop through. The high dropout rate for girls was primarily due to competing after-school activities, but only one of the boys had to miss twice a week for basketball practice, but he was still able to finish almost all of the projects. One of the possibilities that more girls were willing to quit may have been because they had a lower self-efficacy. The competing after-school activities were considered more in the girls' domain, they could possibly have been more comfortable with those other activities.

During the workshop, both males and females stated that they had enjoyed themselves. In general, the girls were very studious and would complete projects on time. The boys however, tended to socialize and be disruptive during times they were supposed to be working. At one point all of the boys were put at their own table to try to minimize their disruptions for the whole group. All of the girls finished each project but some of the boys did not finish their projects. The boys were allowed to take their projects home and work on them there.

Conclusion

All six girls who completed the workshop saw an increase in STEM self-efficacy. Perhaps Sahin & et. al (2014) were correct when discussing that after-school programs can help enhance interest levels in STEM subjects. Constructionism was being used during the workshop; the girls were given a lesson on circuits and then they had the opportunity to construct their own circuit. When mistakes were made, both boys and girls asked the researchers for help. The researchers then scaffolded the girls and boys into figuring out how to fix their circuits. The "maker movement" was incorporated in the workshop, by letting participants build their own circuits. Even though e-textile projects seem to appeal to girls' domains; the boys also maintained interest throughout the workshop.

Parents and teachers also have the power to help raise STEM self-efficacy in middle school girls. Adults don't always realize how much power their words can have on kids. Negative comments should never be used when talking to a child about their performance. The

LilyPad Arduino system can help parents incorporate STEM learning into the household. They can show parents another option for appealing to a girl's domain by incorporating STEM subjects into craft projects. Also, incorporating STEM into traditionally female activities can help show girls that STEM is not just for boys.

The goal of this study was to use the LilyPad Arduino circuit system to engage girls in STEM activities with the potential to help raise self-efficacy levels. Self-efficacy levels may influence girls' activities involving not only school in general but also in STEM subjects in particular. Girls tend to rely on self-efficacy to determine which tasks to participate in and how much effort to exert when involved in STEM activities. The LilyPad Arduino system might not be the perfect answer to help middle school girls become interested in STEM but it does seem to have potential. Efforts to reach girls who do not already have an interest in STEM need to be increased to fully be able to see if LilyPad Arduino has the chance to raise girls' STEM self-efficacy.

Directions for Future Research

One of the biggest limitations the STEM workshop faced was not having a big sample size of girls. The STEM workshop started off with 11 girls but because of other after-school activities, 5 girls had to drop. Another limitation is that we could only meet after school for an hour every day for 4 weeks. In the future, it would be beneficial to have the workshop last for at least 2 hours every day or complete one project per day (if time is allotted). The current study's data is a good starting point at trying to help identify whether the LilyPad Arduino system can help raise girls' STEM self-efficacy. Future research should be aimed at incorporating a larger sample size and multiple schools across different cities.

For future research it would be beneficial for a curriculum be developed, installed in a science class and lessons be taught by a teacher. I believe having a classroom experience and everyone participating in the curriculum, whether they have a high or low self-efficacy would give helpful results. This would help with the self-selection problem, as everyone would have to participate no matter how they feel about STEM.

For the next workshop, the girls should start to learn how to program the LilyPad Arduino computer chips. During the first workshop, the LilyPad Arduino computer chips were already pre-programmed for the girls and boys. Students, especially the boys, vocalized displeasure at not being able to program the Arduinos themselves.

Overall, the present study shows that the LilyPad Arduino has a chance to help raise STEM self-efficacy in girls. These findings suggest that further studies should be performed to help understand if the LilyPad Arduino system can help with the lack of representation of girls in STEM subjects. Future studies should also look at how the teachers who teach STEM subjects might incorporate the LilyPad Arduino system into their teaching to help encourage girls to pursue STEM subjects.

References

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review. 84* (2), 191-215.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychological. 37* (2), 122-147.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Education Psychologist, 28*(2), 117-148.

Bandura, A., & Bussy, K. (2004). On broadening the cognitive, motivational and sociostructural scope of theorizing about gender development and functioning: Comment on Martin, Ruble, and Szkrybalo (2002). *Psychological Bulletin*. *130*(5), 691-701.

Brickhouse, N., Lowery, P., & Schultz,. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching. 37* (50), 441-458.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal Of Research in Science Teaching*. *43*(5). 485-499.

Caldera, Y., Huston, A., & Huston, A. (1989). Social interactions and play patterns of parents and toddlers with feminine, masculine, and neutral toys. *Child Development. 60*(1). 70-76.

Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science, 21*(8), 1051-1057.

Facts over time. Women's Bureau (WB). (2012). Retrieved November 6, 2015. Retrieved from: http://www.dol.gov/wb/stats/facts_over_time.htm

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review. 84*(4), 495-504.

Kafai, Y., Fields, D., & Searle, K. (2014). Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools. *Harvard Educational Review. 84*(4), 532-553.

Kiran, D., & Sungur, S. (2012). Middle school students’ science self-efficacy and its sources: Examination of gender difference. *Journal of Science Education And Technology*. *21*(5). 619-630.

Labor Force Participation. Women's Bureau (WB). (2013). Retrieved November 6, 2015. Retrieved from: http://www.dol.gov/wb/stats/facts_over_time.htm

Landivar, L. (2013). Disparities in STEM employment by sex, race, and Hispanic origin. *American Community Survey Reports.* 1-25.

LilyPad Arduino Main Board. (2015). Retrieved from: https://www.arduino.cc/en/Main/ArduinoBoardLilyPad#

Marchbank, J. & Letherby, G. (2014). *Introduction to gender: Social science perspectives, second edition.* Routledge: New York, NY.

Martin, C.L., & Ruble, D.N. (2010). Patterns of gender development. *Annual Review of Psychology*. *61*(1), 353-381.

Papert, S. (1980). *Mindstorms. Children, Computers and Powerful Ideas.* New York: Basic Books

Papert, S., & Harel, I. (1991) Situating constructionism. In Papert & Harel, *Constructionism,*1-11. Ablex Publishing.

Peppler, K., & Glosson, D. (2013). Stitching circuits: Learning about circuitry through e-textile materials. *Journal Of Science Education And Technology*. *22*(5). 751-763.

Phan, H. (2012). Informational sources, self-efficacy and achievement: A temporally Displaced approach. *Educational Psychology*. *32*(6). 699-726.

Piaget, J. (1962). Play, dreams, and imitation in childhood. New York: Norton

Sahin, A., Ayar, M. C., & Adiguzel, T. (2014). STEM related after-school program activities and associated outcomes on student learning. *Kuram Ve Uvgulamada Egitim Bilimleri*. *14*(1), 309-322.

Shapiro, J.R., & William, A.M. (2012). The role of stereotype threats in undermining girls' and women's performance and interest in STEM fields. *Sex Roles*. *66*(3-4), 175-183

Tenenbaum, H.R., & Leaper, C. (2003). Parent-child conversations about science: The socialization of gender inequities?. *Developmental Psychology*. *39*(1), 34-47.

Uttal, D. H., & Cohen, C. A. (2012). Spatial thinking and STEM education: When, why and how. *Psychology of Learning and Motivation*. *57*, 147-181.

VanMeter-Adams, A., Frankenfeld, C. L., Bases, J., Espina, V., & Liotta, L. A. (2014). Students Who Demonstrate Talen and Interest in STEM are Initially Attracted to STEM through Extracurricular Experiences. *CBE Life Sciences Education*. *13*(4), 687-697

Velayutham, S., Aldridge, J., & Fraser, B. (2011). Development and validation of an instrument to measure Students' Motivation and Self-Regulation in Science Learning. *International Journal of Science Education*, *33*(15), 2159-2179.

APPENDIX A

SCIENCE SELF-EFFICACY SURVEY

Here are some statements about you as a student in **science**. Please read each statement carefully and circle the number that best describes your opinion.

With regard to **science**:	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1. I can master the skills that are taught.	1	2	3	4	5
2. I can figure out how to do difficult work.	1	2	3	4	5
3. Even if the science work is hard, I can learn it.	1	2	3	4	5
4. I can complete difficult work if I try.	1	2	3	4	5
5. I receive good grades.	1	2	3	4	5
6. I can learn the work we do.	1	2	3	4	5
7. I can understand the content taught.	1	2	3	4	5
8. I am good at this subject.	1	2	3	4	5

APPENDIX B

CIRCUIT LESSONS

I. BOOKMARK CIRCUIT LESSONS

Circuit Basics

Voltage and How it Works

You've probably heard that a battery has a certain number of **volts**. This is a measurement of the electrical **potential** produced by the battery.

All those volts are sitting there waiting for you to use them, but there's a catch: **in order for electricity to do any work, it needs to be able to move**. It's kind of like a blown-up balloon; if you pinch it off, there is air in there that *could* do something if it's released, but it won't actually do anything until you let it out.

Unlike air coming out of a balloon, electricity can only flow through materials that can conduct electricity, such as wire. If you connect a wire to a battery you will be giving the electricity a path to follow. But if the wire isn't connected to anything else, the electricity won't have anywhere to go and still won't move.

What makes electricity move? **Electricity wants to flow from a higher voltage to a lower voltage.** This is exactly like the balloon: the pressurized air in the balloon wants to flow from inside the balloon (higher pressure) to outside the balloon (lower pressure). (Demonstrate with an actual balloon). If you create a conductive path between a higher voltage and a lower voltage, electricity will flow along that path. And if you insert something into that path like an LED, the flowing electricity will light up the LED.

So, where do you find a higher voltage and a lower voltage? Here's something really useful to know: **every source of electricity has two sides**. In batteries these sides are called **terminals** and are named **positive** (or "+"), and **negative** (or "-").

Look at the illustrations on your strip of paper. The picture on the right (point to it) is the battery holder. It actually has 4 terminals, two positive and two negative. We're going to be using just two of these – the ones on the left. The little white circles next to the + and the – represent the positive and negative terminals. Does everyone see those? (ask if anyone if having trouble finding them)

In any power supply, the positive side will have a higher voltage than the negative side, which is exactly what we want. In fact, when we measure voltage, we usually say that the negative side is 0 volts, and the positive side is however many volts the supply can provide. The batteries we'll be using have 3 volts.

What have we learned so far?

- Voltage is potential, but electricity needs to flow to do anything useful.
- Electricity needs a path to flow through, which must be an electrical conductor such as wire.

- Electricity will flow from a higher voltage to a lower voltage.
- Batteries always have two sides, called positive and negative, with the positive side a higher voltage than the negative side.

Now let's talk about how to get the electricity to light up an LED. If we connect the positive side of the battery through an LED and back to the negative side of the battery; electricity, or **current**, will flow through the LED and make it light up!

This circular path, which is always required to get electricity to flow and do something useful, is called a circuit. A circuit is a path that starts and stops at the same place, which is exactly what we're doing.

The reason we want to build circuits is to make electricity do useful things for us. The way we do that is by putting things in the circuit that use the current flow to light up, make noise, run programs, etc.

But for now, let's learn about two special cases of circuit: **short circuit**, and **open circuit**. Knowing about these will help tremendously when you're troubleshooting your own circuits.

Short Circuit

DON'T DO THIS, but if you connect a wire directly from the positive to the negative side of a battery, you'll create what is called a **short circuit**. This is a very bad idea. It causes too much electricity to flow through the circuit and back into the battery too quickly, which could cause your wire to burn up, drain your battery, or even start a fire. So you need to be very careful that the thread from the positive line and the thread from the negative line never touch each other.

Open Circuit

The opposite of a short circuit is an **open circuit**. This is a circuit where the loop isn't fully connected (and therefore this isn't really a circuit at all). Nothing will get damaged by this "circuit", but your circuit won't work. This is usually due to a broken connection or a loose wire, so you'll need to make sure all of your connections are secure and tight.

We are going to be sewing a circuit connecting the battery to the LED using this conductive thread.

The first step is for you to draw your circuit on the piece of paper you have, drawing a dashed line in red for the positive line and a dashed line in black for the negative line. Remember you want to connect the positive terminal on the battery to the positive input on the LED, and the negative output on the LED to the negative terminal on the battery.

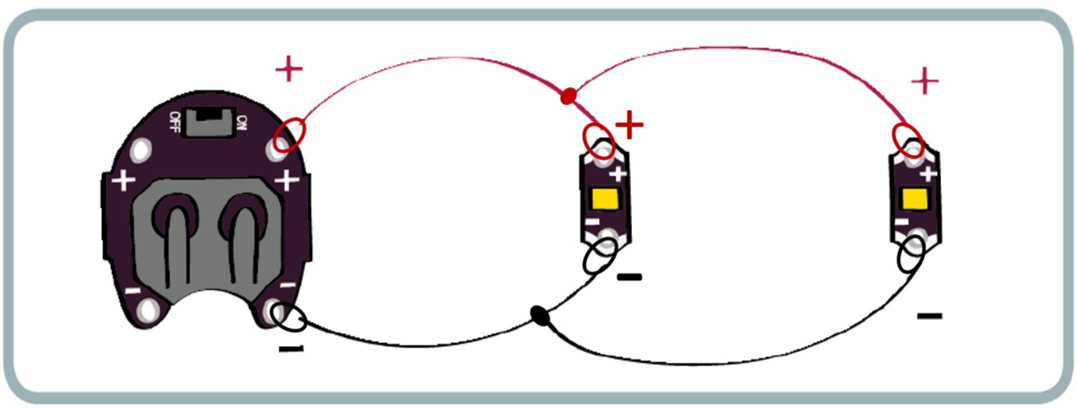
II. KEYCHAIN CURCUIT LESSON

First, let's review **how current flows** through a circuit. Does current flow from a high voltage to a lower voltage or from a low voltage to a higher voltage? Remember the air in the balloon . . . Current flows from a high voltage to a lower voltage in a circuit. Some amount of current will flow through every path it can take to get to the point of lowest voltage, in our case the negative terminal on the battery.

In order to light up two lights, we're going to learn to create a parallel circuit. The first thing we need to talk about is the concept of a **node**. Does anybody know what a **node** is in a circuit? It's the electrical connection between two or more components. The nodes are the wires (or in our case conductive thread) between components.

Parallel Circuits

If components share *two* common nodes, they are in parallel. Here's an example of two LED lights in a parallel circuit with a battery:



From the positive battery terminal, current flows to the positive side of the first LED and then to the positive side of the second LED. The node that connects the battery to the first LED is also connected to the second LED. The negative ends of the LEDs are connected together in the same way, and then connected back to the negative terminal of the battery. There two distinct paths that current can take before returning to the battery. Can someone point out what those two paths are? This is a parallel circuit.

Here's how to stitch a parallel circuit. The path of thread connecting one point to another is called a **trace**.

You create the trace from the battery's positive terminal to the first LED's positive side exactly the same way you did with the bookmark project. Next you need to connect a second trace to the trace you just created. To do this, you loop the new trace's thread around the old trace three times, and then stitch a path to the positive side of the second LED, looping it 3 times and knotting it just like you did before.

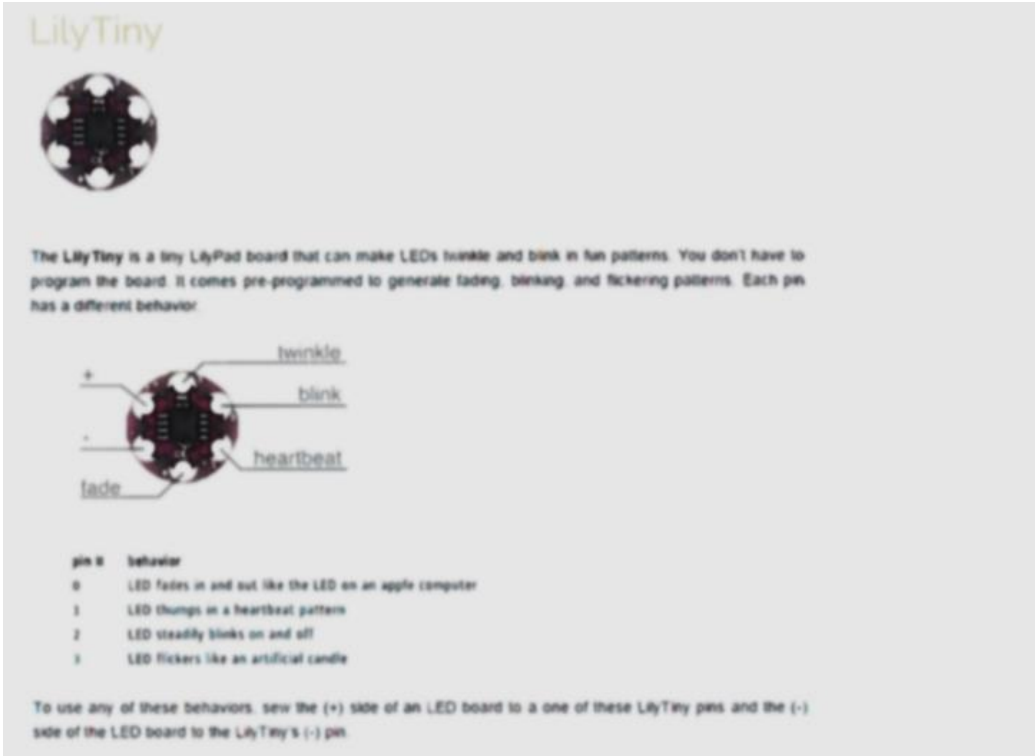
Then you repeat the same pattern of stitching to connect the battery's negative terminal to the negative side of the first LED, and connecting a second trace to that trace and stitching to the negative side of the second LED.

III. BALL CAP CIRCUIT LESSON

Today we're going to learn about something new we can incorporate into our circuits that's very exciting. See this little tiny thing here? (Hold up LilyTwinkle) What do you think this is? It's actually a computer chip that you can sew into your circuits! The little square in the middle is the computer chip and there are holes around the outside that you can sew through to incorporate it into your circuits. It's called a LilyTwinkle because the Sewing Circuits system that all of these components come from is called LilyPad Arduino. So that's the "Lily" part, and the "Twinkle" part is because this little computer chip is pre-programmed with a computer program that will make all of your lights twinkle on and off in a random pattern. With the LilyPad Arduino system you can even learn to write your own computer programs to download onto a LilyPad computer chip. We're not going to be doing that in this Workshop, but it's something that you could learn about in the future.

What you have on your paper is an enlarged view of all of the components that we're going to use to sew the circuit for your ball cap. You see the battery pack there on the left, and that part in the middle is the LilyTwinkle. In this circuit you're about to draw the 4 LEDs are arranged in a circle around the LilyTwinkle. So you'll be connecting positive to positive and negative to negative on the battery holder and the LilyTwinkle. The other four holes in the Lily Twinkle are all positive, so you'll connect those to the positive side of each LED. Then you'll need to connect all of the negative sides of the LEDs back to negative on the battery. Remember how you made connections between the different circuits on the key fob by connecting to the middle of a row of stitching and go ahead and give it a try. Remember to draw positive in red and negative in black.

IV. T-SHIRT CIRCUIT LESSON



LilyTiny

The **LilyTiny** is a tiny LilyPad board that can make LEDs twinkle and blink in fun patterns. You don't have to program the board. It comes pre-programmed to generate fading, blinking, and flickering patterns. Each pin has a different behavior.

pin #	behavior
0	LED fades in and out like the LED on an apple computer
1	LED thumps in a heartbeat pattern
2	LED steadily blinks on and off
3	LED flickers like an artificial candle

To use any of these behaviors, sew the (+) side of an LED board to a one of these LilyTiny pins and the (-) side of the LED board to the LilyTiny's (-) pin.

Figure 2. Lesson plan created for the LilyTiny. Circuit lesson for the t-shirt.

APPENDIX C

TEMPLATES

BOOKMARK

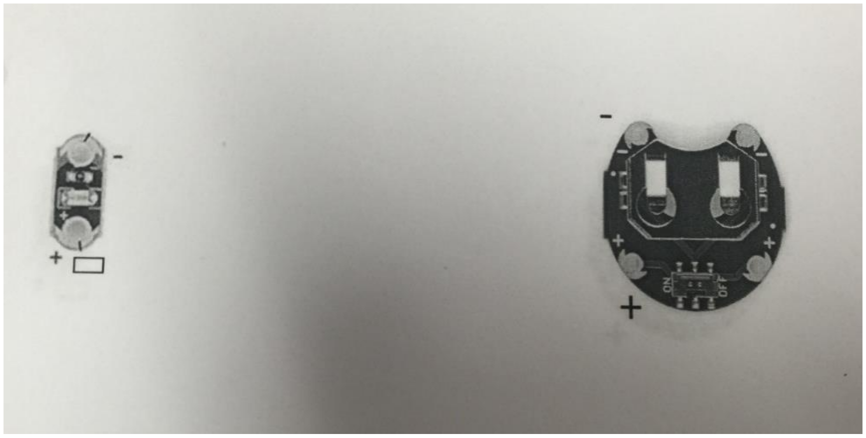


Figure 2. Bookmark template the children used to practice drawing circuits.

KEYCHAIN

Figure 3. Keychain template the children used to practice drawing circuits.

BALL CAP

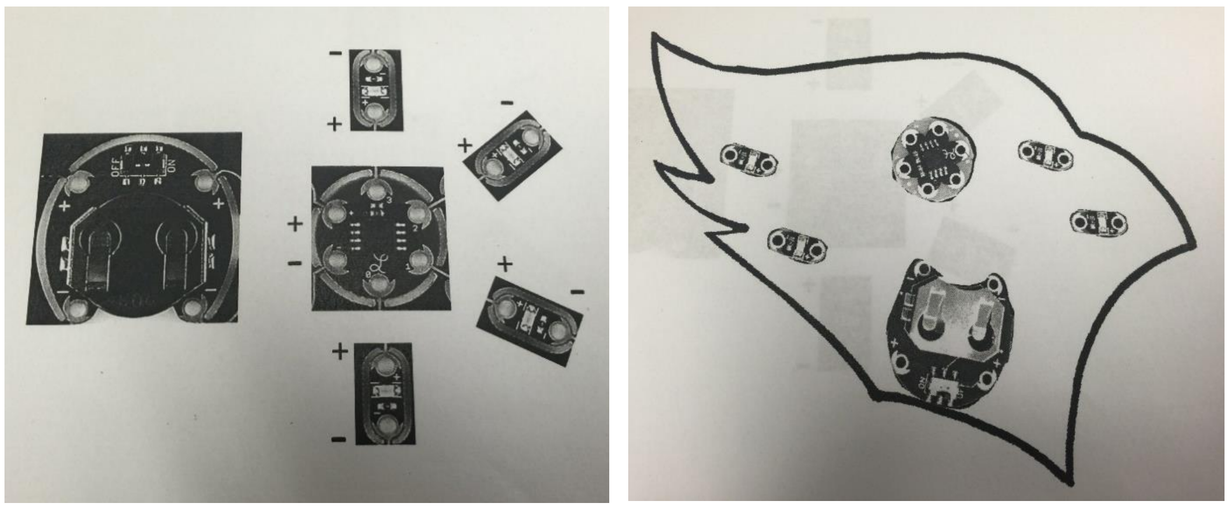


Figure 4. Ball cap templates the children used to practice drawing circuits.

T-SHIRT

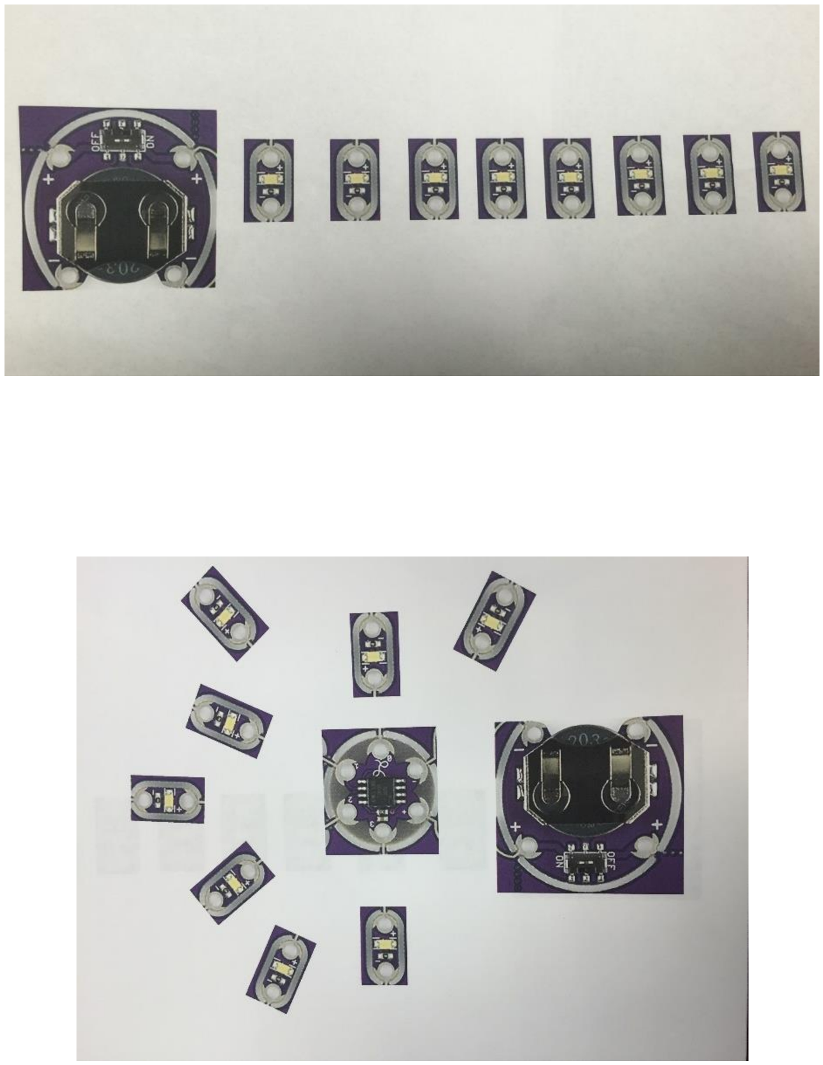


Figure 5. T-shirt templates the children used to practice drawing circuits.

APPENDIX D

FINISHED PROJECTS

BOOKMARK

Ladybug Moon and Stars

Figure 6. Examples of finished bookmarks completed by the students.

KEYCHAIN

Monkey Cardinal

Figure 7. Examples of finished key chains completed by the students.

BALL CAP

Free for all	Cardinal

Figure 8. Examples of finished ball caps completed by the students.

Free for all

Figure 9. Examples of finished t-shirts completed by the students.

APPENDIX E

IRB PROTOCOL

UNIVERSITY OF ARKANSAS INSTITUTIONAL REVIEW BOARD

PROTOCOL FORM

The University Institutional Review Board recommends policies and monitors their implementation, on the use of human beings as subjects for physical, mental, and social experimentation, in and out of class. . . . Protocols for the use of human subjects in research and in class experiments, whether funded internally or externally, must be approved by the (IRB) or in accordance with IRB policies and procedures prior to the implementation of the human subject protocol. . . Violation of procedures and approved protocols can result in the loss of funding from the sponsoring agency or the University of Arkansas and may be interpreted as scientific misconduct. *(see Faculty Handbook*)

Supply the information requested in items 1-14 as appropriate. Type entries in the spaces provided using additional pages as needed. In accordance with college/departmental policy, submit the original and one copy of this completed protocol form and all attached materials to the appropriate Human Subjects Committee. In the absence of an IRB-authorized Human Subjects Committee, submit the original and one copy of this completed protocol form and all attached materials to the IRB, Attn: Compliance Officer, OZAR 118, 575-3845.

1. Title of Project **USING INNOVATIVE TECHNOLOGY TO ENGAGE RURAL GIRLS IN STEM LEARNING: PILOT STUDY**

2. (Students **must** have a faculty member supervise the research. The faculty member must sign this form and all researchers and the faculty advisor should provide a campus phone number.)

	Name	Department	Email Address	Campus Phone
Principal Researcher	Glenda Revelle	HESC	grevelle@uark.edu	(479) 575-2192
Co-Researcher	Laurie Apple	HESC	lapple@uark.edu	(479) 575-4576

Co-Researcher Zola Moon HESC zmoon@uark.edu (479) 575-5123

Co-Researcher Kathy Smith HESC kasmith@uark.edu (479) 575-2577

Research Assistant Kara Kaiser HESC klkaiser@uark.edu (479 575-2500

3.Researcher(s) status. Check all that apply.

X Faculty Staff **X Graduate Student** Undergraduate Student

4. Project type

X Faculty Research	**X Thesis** / Dissertation	☐ Class Project	☐ Independent Study /
☐ Staff Research	☐ M.A.T. Research	☐ Honors Project	Educ. Spec. Project

5. Is the project receiving extramural funding?

☐ No **X Yes**. Specify the source of funds

Arkansas Agricultural Experiment Station (AAES)

6.Brief description of the purpose of proposed research and all procedures involving people. Be specific. Use additional pages if needed. (**Do not** send thesis or dissertation proposals. Proposals for extramural funding must be submitted in full.)

The overall goal of this research is to engage young, rural girls in science, technology, engineering and mathematics (STEM) learning by bringing STEM to traditionally female domains like sewing, crafting, fashion and apparel design. Research shows that middle school is a critical time period for engaging and retaining students' interest in STEM topics if they are to get the education needed in their remaining pre-college years to qualify them to pursue STEM college majors and STEM careers. This is the pilot study portion of the larger project.

The project team will design and implement a scope and sequence curriculum of e-textile design activities, using the Lily-Pad Arduino textile circuit kit, to engage 10-12 year olds in STEM learning. In the pilot user study, we will conduct two 20-hour workshops in the context of middle-school after school programs, one in which approximately 25 children use the e-textile activities designed in this project and one in which approximately 25 children use a traditional kit that is designed to teach the fundamentals of circuit design to children. In addition there will be a third group of approximately 25 children (serving as a control group) who only participate in the pre- and post-assessment, with no workshop. Each of these three groups of children will be participants in three different middle school after-school programs. One week before the workshop and then again one week afterwards, children will be interviewed regarding STEM interests, and the STEM Semantics Survey and STEM Career Interest Questionnaire (both developed by Tyler-Wood, Knezek, & Christensen, 2010) and the Generalized Self-Efficacy Scale (Schwarzer & Jerusalem, 1995) will be administered. Children in the workshops will be videotaped during the first 2 hours and the last 2 hours of the workshops, and their behaviors will be coded for STEM thinking and STEM inquiry practices. In addition, adult leaders of the after school programs will be interviewed regarding their perceptions of the project.

The goals of this pilot study are to (a) examine comprehension and enjoyment of the activities, (b) identify what's working and what's not working in the activities so that revisions can be made before the more ambitious study with rural girls is conducted, (c) investigate how well the activities succeed in supporting girls in engaging in STEM thinking and STEM activity processes, and (d) compare the experiences and responses of the children using the e-textile activities to those of the children using the traditional circuitry kit. Results of this pilot research will be used to revise, refine, and improve the e-textile activities so that they may be field tested with a rural sample in Year 2.

Procedures involving people:

Data for this study will be collected through pre-post interviews, assessment instruments, and video-recorded observations. Participants will be children 10-12 years of age who will participate in

the e-textile or traditional circuit design workshops and a control group who only completes the pre-post assessment instruments.

_**75**_ Children under 14 __0__ Children 14-17 __**0**_ UA students __**6**__ Adult non-students (18yrs and older)

7.Estimated number of participants (complete all that apply)

8. Anticipated dates for contact with participants:

First Contact: **April 1, 2015** Last Contact: **April 1, 2016**

9. Informed Consent procedures: The following information must be included in any procedure: identification of researcher, institutional affiliation and contact information; identification of Compliance Officer and contact information; purpose of the research, expected duration of the subject's participation; description of procedures; risks and/or benefits; how confidentiality will be ensured; that participation is voluntary and that refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled. See *Policies and Procedures Governing Research with Human Subjects*, section 5.0 Requirements for Consent.

X Signed informed consent will be obtained. Form attached

☐ Modified informed consent will be obtained. Attach copy of form.

☐ Other method (e.g., implied consent). Please explain on attached sheet.

☐ Not applicable to this project. Please explain on attached sheet.

10. Confidentiality of Data: All data collected that can be associated with a subject/respondent must remain confidential. Describe the methods to be used to ensure the confidentiality of data obtained.

All participants will be identified by an ID number only, there will be no participant names or other personal identifying information stored in the data. This research project will utilize the content management system "RazorVault" at the University of Arkansas to share project data. Access to materials not containing sensitive data will be assigned publicly accessible security credentials within RazorVault. The public will be able to search these materials via a common

web-based search interface. Access to materials containing sensitive information will require a request to the principal investigator for processing. No attempt will be made to track individuals subsequent to completion of the activities. The final database will not contain any information that will allow the researchers to identify individuals who provide the data.

11. Risks and/or Benefits:

Risks: Will participants in the research be exposed to more than minimal risk? Yes **X No**
Minimal risk is defined as risks of harm not greater, considering probability and magnitude, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests. Describe any such risks or discomforts associated with the study and precautions that will be taken to minimize them.

There are no known risks associated with this project.

Benefits: Other than the contribution of new knowledge, describe the benefits of this research.

Participants will be given the opportunity to create e-textiles for themselves or for others. Participants will have an opportunity to increase sewing skills, engage in STEM thinking and STEM activity processes, and learn about career possibilities in STEM fields.

12. Check all of the following that apply to the proposed research. Supply the requested information below or on attached sheets:

☐ A. Deception of or withholding information from participants. Justify the use of deception or the withholding of information. Describe the debriefing procedure: how and when will the subject be informed of the deception and/or the information withheld?

☐ B. Medical clearance necessary prior to participation. Describe the procedures and note the safety precautions to be taken.

☐ C. Samples (blood, tissue, etc.) from participants. Describe the procedures and note the safety precautions to be taken.

☐ D. Administration of substances (foods, drugs, etc.) to participants. Describe the procedures and note the safety precautions to be taken.

☐ E. Physical exercise or conditioning for subjects. Describe the procedures and note the safety precautions to be

taken.

X F. Research involving children. How will informed consent from parents or legally authorized representatives as well as from subjects be obtained? **See attached letter and consent form.**

☐ G. Research involving pregnant women or fetuses. How will informed consent be obtained from both parents of the fetus?

☐ H. Research involving participants in institutions (cognitive impairments, prisoners, etc.). Specify agencies or institutions involved. Attach letters of approval. Letters must be on letterhead with original signature; electronic transmission is acceptable.

☐ I. Research approved by an IRB at another institution. Specify agencies or institutions involved. Attach letters of approval. Letters must be on letterhead with original signature; electronic transmission is acceptable.

☐ J. Research that must be approved by another institution or agency. Specify agencies or institutions involved. Attach letters of approval. Letters must be on letterhead with original signature; electronic transmission is acceptable.

13. Checklist for Attachments

The following are attached:
F **Consent form (if applicable) or**
F **Letter to participants, written instructions, and/or script of oral protocols indicating clearly the information in item #9.**
F Letter(s) of approval from cooperating institution(s) and/or other IRB approvals (if applicable)
F **Data collection instruments**

14. Signatures

I/we agree to provide the proper surveillance of this project to insure that the rights and welfare of the human subjects/respondents are protected. I/we will report any adverse reactions to the committee. Additions to or changes in research procedures after the project has been approved will be submitted to the committee for review. I/we agree to request renewal of approval for any project when subject/respondent contact continues more than one year.

[redacted]

Parental Consent Letter for the two Workshop groups

April 1, 2015

Dear Parents, Caregivers, and Guardians,

We would like to invite your child to participate in a pilot study conducted by researchers from the University of Arkansas. The purpose of this study is to try out some engaging, fun, and instructive science experiences that we have developed for middle-school aged children.

Your child is invited to participate in a program that will last one hour a day during the after-school program for 4 weeks (a total of 20 hours). Researchers from the University of Arkansas will conduct the program, which will provide your child with the opportunity to create several projects using electronic circuits. These projects are designed by the UA researchers to be fun and engaging, as well as educational. All children will be closely supervised and given personal instruction by trained UA researchers.

We would like to video tape your child during the first 2 hours and the last 2 hours of the study so we can determine how effective these projects are for encouraging children's science thinking and learning. The tapes will only be seen by our staff of researchers. Your family name will not be revealed to anyone, the tapes will be titled using ID numbers only.

We would also like to have your child complete a questionnaire at the beginning and at the end of the program. This information will help us determine how well this program works for getting middle-school students interested in science learning and activities.

We expect this experience to be fun and interesting for your child, and we do not expect any risks. You and/or your child may decide to stop taking part at any time and without giving any reason.

If you give permission for your child to participate, please sign the attached Consent Form and return it to________________________________.

Thank you for your cooperation. We greatly appreciate it. If you have any questions, please feel free to contact me at 479.575.2192. If you have any concerns or complaints about the study, you may contact the University of Arkansas Research Compliance officer, Iroshi (Ro) Windwalker at 479.575.2208 or irb@uark.edu.

Sincerely,

Glenda Revelle, Ph.D.

Associate Professor

Human Development and Family Sciences

University of Arkansas

Parental Consent Letter for the Control group

April 1, 2015

Dear Parents, Caregivers, and Guardians,

We would like to invite your child to participate in a pilot study conducted by researchers from the University of Arkansas. The purpose of this study is to help us learn about middle school students' attitudes toward and interest in science learning, to inform our development of engaging and fun science activities for this age group.

Researchers from the University of Arkansas will attend your child's after-school program on two occasions during the current term. We would like to have your child complete a questionnaire on each of those two occasions. This information will help us understand middle school students' attitudes toward and interest in science learning so that we can do an effective job of developing fun and interesting science activities for middle school students.

We expect this experience to be interesting for your child, and we do not expect any risks. You and/or your child may decide to stop taking part at any time and without giving any reason.

If you give permission for your child to participate, please sign the attached Consent Form and return it to_________________________________.

Thank you for your cooperation. We greatly appreciate it. If you have any questions, please feel free to contact me at 479.575.2192. If you have any concerns or complaints about the study, you may contact the University of Arkansas Research Compliance officer, Iroshi (Ro) Windwalker at 479.575.2208 or irb@uark.edu.

Sincerely,

Glenda Revelle, Ph.D.

Associate Professor

Human Development and Family Sciences

University of Arkansas

Consent form for the two workshop groups

Consent Form for the University of Arkansas Middle School Science Study

I have read the letter about the University of Arkansas research project that will be conducted at _______________________. I understand that my child will be engaged in this program's activities for an hour each day for 4 weeks, and that the first 2 hours and last 2 hours will be videotaped. I also understand my child will be asked to answer a questionnaire at the beginning and at the end of the program. I understand that even if I agree for my child to participate he/she may decide to stop at any time.

If you have any questions, please feel free to contact Dr. Glenda Revelle at 479.575.2192 or grevelle@uark.edu. If you have any concerns or complaints about the study, you may contact the University of Arkansas Research Compliance officer, Iroshi (Ro) Windwalker at 479.575.2208 or irb@uark.edu.

Please check ONE of the lines below:

_______ My child **has my permission** to participate in the study.

_______ My child **does not have my permission** to participate in the study.

If you do give permission for your child to participate, please fill out the Parent section below and ask your child to fill out the Child section below. Thank you for considering your child's participation in this project.

Parent: I have talked this over with my child and agree for him/her to participate. I understand that she/he may stop at any time if he/she chooses to do so.

________________________________ ________________________________

Parent's Name (please print) Parent's email address

________________________________ ________________________________

Parent's phone number Parent's Signature

____

Date

Child: I have talked this over with my parent/guardian(s) and agree to participate. I understand that I can stop at any time even if my parent/guardian(s) has agreed for me to participate.

________________________________ ________/__________/______________

Child's Name (please print) Child's date of birth (please include year)

Male / Female__________ ____

Child's Gender (please circle one) Child's signature

Please return to ____.

Consent form for the control group

Consent Form for the University of Arkansas Middle School Science Study

I have read the letter about the University of Arkansas research project that will be conducted at _______________________. I understand that my child will be asked to answer a questionnaire on two occasions during his/her after-school program. I also understand that even if I agree for my child to participate he/she may decide to stop at any time.

If you have any questions, please feel free to contact Dr. Glenda Revelle at 479.575.2192 or grevelle@uark.edu. If you have any concerns or complaints about the study, you may contact the University of Arkansas Research Compliance officer, Iroshi (Ro) Windwalker at 479.575.2208 or irb@uark.edu.

Please check ONE of the lines below:

_______ My child **has my permission** to participate in the study.

_______ My child **does not have my permission** to participate in the study.

If you do give permission for your child to participate, please fill out the Parent section below and ask your child to fill out the Child section below. Thank you for considering your child's participation in this project.

Parent: I have talked this over with my child and agree for him/her to participate. I understand that she/he may stop at any time if he/she chooses to do so.

________________________________ ________________________________

Parent's Name (please print) Parent's email address

________________________________ ____

Parent's phone number Parent's Signature

____

Date

Child: I have talked this over with my parent/guardian(s) and agree to participate. I understand that I can stop at any time even if my parent/guardian(s) has agreed for me to participate.

________________________________ ________/__________/______________

Child's Name (please print) Child's date of birth (please include year)

Male / Female__________ ____

Child's Gender (please circle one) Child's signature

Please return to ____.

STEM Semantics Survey (developed by Tyler-Wood et al., 2010).

STEM Semantics Survey

Gender: M / F

This five-part questionnaire is designed to assess your perceptions of scientific disciplines. It should require about 5 minutes of your time. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.

ID: _______________ **School:**_____________	Use the assigned ID or the year and day of your birthday (ex: 9925 if born on the 25th day of any month in 1999.

Instructions: Choose one circle between each adjective pair to indicate how you feel about the object.

To me, SCIENCE is:

1.	fascinating	①	②	③	④	⑤	⑥	⑦	mundane
2.	appealing	①	②	③	④	⑤	⑥	⑦	unappealing
3.	exciting	①	②	③	④	⑤	⑥	⑦	unexciting
4.	means nothing	①	②	③	④	⑤	⑥	⑦	means a lot
5.	boring	①	②	③	④	⑤	⑥	⑦	interesting

To me, MATH is:

1.	boring	①	②	③	④	⑤	⑥	⑦	interesting
2.	appealing	①	②	③	④	⑤	⑥	⑦	unappealing
3.	fascinating	①	②	③	④	⑤	⑥	⑦	mundane
4.	exciting	①	②	③	④	⑤	⑥	⑦	unexciting
5.	means nothing	①	②	③	④	⑤	⑥	⑦	means a lot

To me, ENGINEERING is:

1.	appealing	①	②	③	④	⑤	⑥	⑦	unappealing
2.	fascinating	①	②	③	④	⑤	⑥	⑦	mundane
3.	means nothing	①	②	③	④	⑤	⑥	⑦	means a lot
4.	exciting	①	②	③	④	⑤	⑥	⑦	unexciting
5.	boring	①	②	③	④	⑤	⑥	⑦	interesting

To me, TECHNOLOGY is:

1.	appealing	①	②	③	④	⑤	⑥	⑦	unappealing
2.	means nothing	①	②	③	④	⑤	⑥	⑦	means a lot
3.	boring	①	②	③	④	⑤	⑥	⑦	interesting
4.	exciting	①	②	③	④	⑤	⑥	⑦	unexciting
5.	fascinating	①	②	③	④	⑤	⑥	⑦	mundane

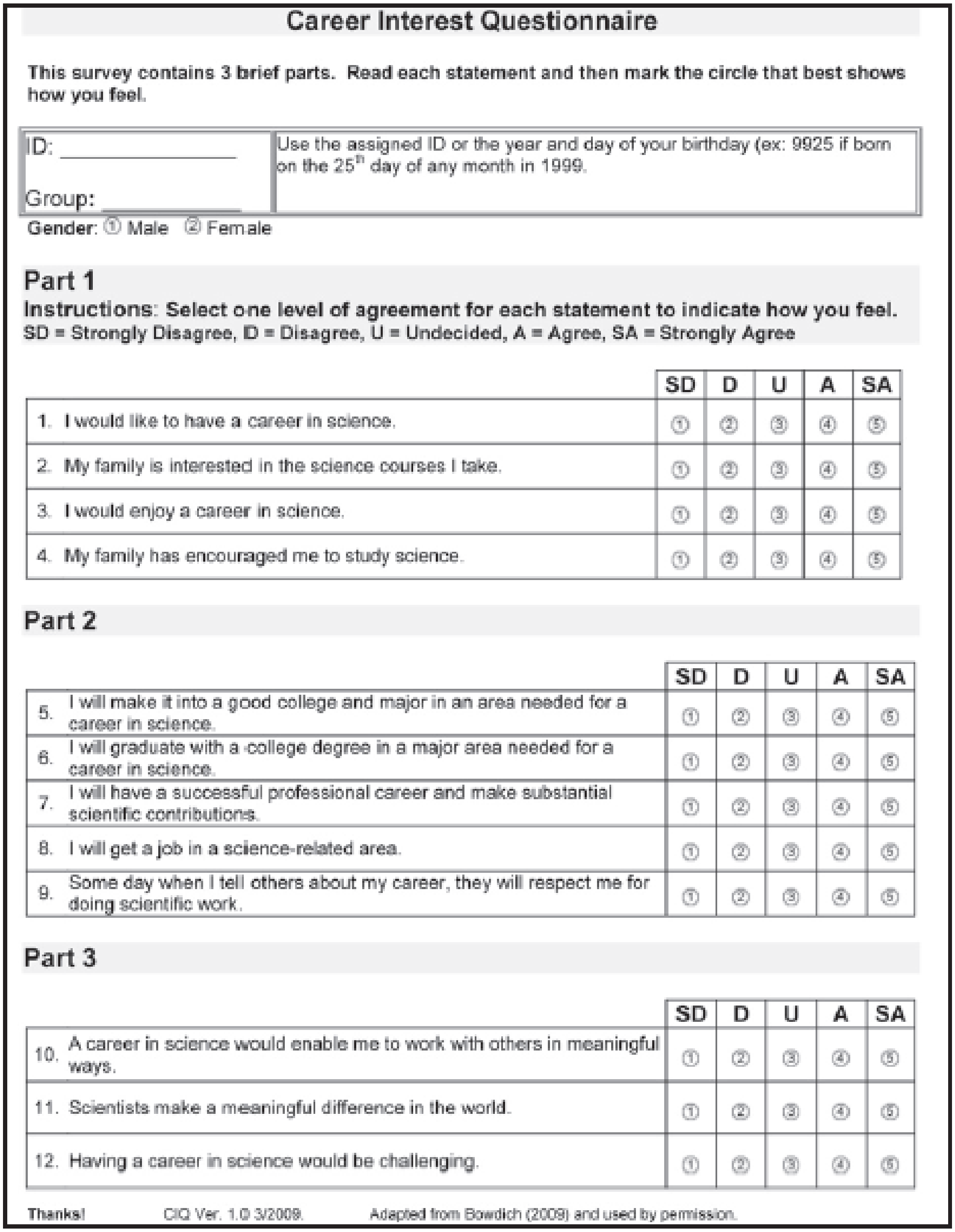
To me, a CAREER in science, technology, engineering, or mathematics (is):

1.	means nothing	①	②	③	④	⑤	⑥	⑦	means a lot
2.	boring	①	②	③	④	⑤	⑥	⑦	interesting
3.	exciting	①	②	③	④	⑤	⑥	⑦	unexciting
4.	fascinating	①	②	③	④	⑤	⑥	⑦	mundane
5.	appealing	①	②	③	④	⑤	⑥	⑦	unappealing

Thank you for your time.
STEM v. 1.0 by G. Knezek & R. Christensen 4/2008

Tyler-Wood, T., Knezek, G., & Christensen, R. (2010). Instruments for assessing interest in STEM content and careers. *Journal of Technology and Teacher Education*, *18*(2), 345-368.

STEM Career Interest Questionnaire (developed by Tyler-Wood et al., 2010).



Career Interest Questionnaire

This survey contains 3 brief parts. Read each statement and then mark the circle that best shows how you feel.

ID: ______________ Group: ______________	Use the assigned ID or the year and day of your birthday (ex: 9925 if born on the 25th day of any month in 1999.

Gender: ① Male ② Female

Part 1

Instructions: Select one level of agreement for each statement to indicate how you feel.
SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

	SD	D	U	A	SA
1. I would like to have a career in science.	①	②	③	④	⑤
2. My family is interested in the science courses I take.	①	②	③	④	⑤
3. I would enjoy a career in science.	①	②	③	④	⑤
4. My family has encouraged me to study science.	①	②	③	④	⑤

Part 2

	SD	D	U	A	SA
5. I will make it into a good college and major in an area needed for a career in science.	①	②	③	④	⑤
6. I will graduate with a college degree in a major area needed for a career in science.	①	②	③	④	⑤
7. I will have a successful professional career and make substantial scientific contributions.	①	②	③	④	⑤
8. I will get a job in a science-related area.	①	②	③	④	⑤
9. Some day when I tell others about my career, they will respect me for doing scientific work.	①	②	③	④	⑤

Part 3

	SD	D	U	A	SA
10. A career in science would enable me to work with others in meaningful ways.	①	②	③	④	⑤
11. Scientists make a meaningful difference in the world.	①	②	③	④	⑤
12. Having a career in science would be challenging.	①	②	③	④	⑤

Thanks! CIQ Ver. 1.0 3/2009. Adapted from Bowdich (2009) and used by permission.

Tyler-Wood, T., Knezek, G., & Christensen, R. (2010). Instruments for assessing interest in STEM content and careers. *Journal of Technology and Teacher Education*, *18*(2), 345-368.

Generalized Self-Efficacy Scale (Schwarzer & Jerusalem, 1995)

1	I can always manage to solve difficult problems if I try hard enough. 1 = Not at all true 2 = Hardly true 3 = Moderately true 4 = Exactly true
2	If someone opposes me, I can find the means and ways to get what I want. 1 = Not at all true 2 = Hardly true 3 = Moderately true 4 = Exactly true
3	It is easy for me to stick to my aims and accomplish my goals. 1 = Not at all true 2 = Hardly true 3 = Moderately true 4 = Exactly true
4	I am confident that I could deal efficiently with unexpected events. 1 = Not at all true 2 = Hardly true 3 = Moderately true 4 = Exactly true
5	Thanks to my resourcefulness, I know how to handle unforeseen situations. 1 = Not at all true 2 = Hardly true 3 = Moderately true 4 = Exactly true
6	I can solve most problems if I invest the necessary effort. 1 = Not at all true 2 = Hardly true 3 = Moderately true 4 = Exactly true
7	I can remain calm when facing difficulties because I can rely on my coping abilities. 1 = Not at all true 2 = Hardly true 3 = Moderately true 4 = Exactly true

8	When I am confronted with a problem, I can usually find several solutions. 1 = Not at all true 2 = Hardly true 3 = Moderately true 4 = Exactly true
9	If I am in trouble, I can usually think of a solution. 1 = Not at all true 2 = Hardly true 3 = Moderately true 4 = Exactly true
10	I can usually handle whatever comes my way. 1 = Not at all true 2 = Hardly true 3 = Moderately true 4 = Exactly true

Schwarzer, R., & Jerusalem, M. (1995). Generalized Self-Efficacy scale. In J. Weinman, S. Wright, & M. Johnston, Measures in health psychology: A user’s portfolio. Causal and control beliefs (pp. 35- 37).

PROTOCOL APPROVAL FORM

(To be returned to IRB Program Manager with copy of completed protocol form and attachments)

Human Subjects Committee Use Only (In absence of IRB-authorized Human Subjects Committee, send protocol to IRB.)

Recommended Review Status

☐ Human Subjects Committee can approve as exempt because this research fits in the following category of research as described in section 9.02 of the IRB policies and procedures **(Cite reasons for exempt status.)**:

Printed Name and

Signature of the HSC Chair ____ Date

****

☐ Expedited Review by a designated member of the IRB because this research fits in the following category of research as described in section 9.03 of the IRB policies and procedures **(Cite reasons for expedited status.)**:

Printed Name and

Signature of the HSC Chair ____ Date

****

☐ Requires Full Review by the IRB because this research fits in the following category of research as described in section 9.04 of the IRB policies and procedures **(Cite reasons for full status.)**:

Printed Name and

Signature of the HSC Chair ____ Date

IRB/RSSP Use Only

Project Number ______________________________________ Received RSSP

Sent to: ____ Date:

Final Status

☐ Approved as **Exempt** under section 9.02 of the IRB Policies and Procedures (**Cite reasons for exemption.**):

☐ Approved as **Expedited** under Section 9.03 of the IRB Policies and Procedures because **(Cite reasons for expedited status.)**

Printed Name and

Signature: ____ ________________ Date

IRB (for the Committee)

☐ Approved by **Full** review under Section 9.04 of the IRB as meeting requirements of the IRB Policies and Procedures.

Printed Name and

Signature: ____ Date

IRB Chairperson

APPENDIX F

INSTITUTIONAL REVIEW BOARD APPROVAL FORM

UNIVERSITY OF ARKANSAS

Office of Research Compliance
Institutional Review Board

April 17, 2015

MEMORANDUM

TO:	Glenda Revelle Laurie Apple Zola Moon Kathy Smith Kara Kaiser
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	15-02-560
Protocol Title:	*Using Innovative Technology to Engage Rural Girls in STEM Learning: Pilot Study*
Review Type:	☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB
Approved Project Period:	Start Date: 04/17/2015 Expiration Date: 03/11/2016

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (https://vpred.uark.edu/units/rscp/index.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 81 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 109 MLKG Building, 5-2208, or irb@uark.edu.

109 MLKG • 1 University of Arkansas • Fayetteville, AR 72701-1201 • (479) 575-2208 • Fax (479) 575-6527 • Email irb@uark.edu