SOLDER AND WIRE OR NEEDLE AND THREAD: CAN THE TOOLS WE USE CHANGE THE WAY WE THINK?

Final Report for the Amir Lopatin Fellowship

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April 13, 2016

ABSTRACT

The gender gap in computing has persisted—and grown—over the past 40 years. One class of solutions offered as a way to close the gap are software and hardware design tools created for girls. This study compares one such construction kit—the Adafruit Flora—to a comparable kit that was not designed with girls in mind—the Arduino Leonardo. N=49 students from an all-girls middle school were recruited to take part in the study. N=10 girls learned to use the Adafruit Flora over the course of a week-long workshop, N=10 girls learned to use the Arduino Leonardo, and N=29 girls served as the control group. All of the girls in the study took a set of pre- and post-workshop surveys of attitudes, including a pair of Go/No-Go Association Tests. The design of the construction kit had a weak effect, at best, on the girls' attitudes. These findings cast doubt on prior claims as to the effectiveness of gendered construction kits on girls' interest in and attitudes towards computing.

INTRODUCTION

According to the latest statistics released by the US Department of Education, 55,000 students received a degree in computer science in 2014. Of those students, only 10,000 were women. An article in Newsweek describes the situation perfectly. "The gender gap is real and takes many forms… Despite great strides by women in other formerly male fields, such as law and medicine, women are turning away from the computer industry. Men earning computer-science degrees outnumber women 3 to 1 and the gap is growing" (Kantrowitz, 1994).

There are two things that I find alarming about this quote. First, the quote is from 1994. This means that the gender gap in computer science has been a problem recognized by popular media for over 20 years. But there is another thing that is even more worrying than this. The gender gap in computer science stood at 3 to 1 in 1994, but in 2014 it stands at 4.5 to 1. This means that not only has the gender gap in computing persisted for over 20 years, but it has gotten wider.

For an illustration of how the gap has (mostly) grown over the past 40 years, see Figure 1. One way of quantifying the size of the gap is by taking the percentage of females graduating with a bachelor's degree in computer science. In 1970, 14% of graduates were female. The gap shrunk considerably over the next 16 years, and in 1986 37% of graduates in computer science were female. However, since then the gap has widened considerably, and in 2007 only 18% of graduates were women. The gender gap has remained at this level since 2007 (Snyder & Dillow, 2015).

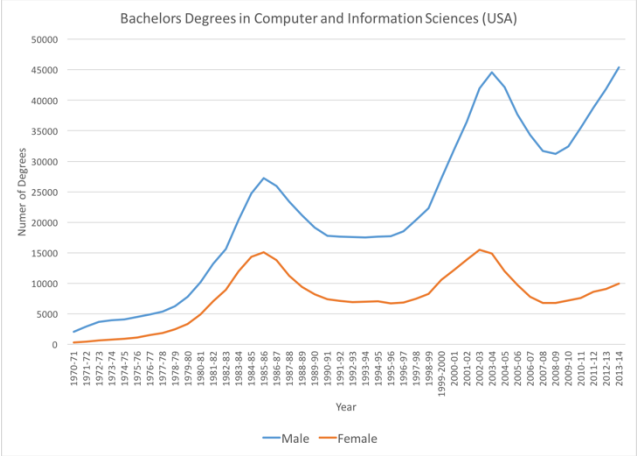

FIGURE 1: DEGREES IN COMPUTING FROM 1970 TO 2014 (USA)

CLOSING THE GENDER GAP

Although some argue that concern about the gender gap is blown out of proportion (Cummins, 2015), most argue that closing the gender gap is a high priority. In the past few years, large technology corporations have joined the call to increase participation in computing. Google, Apple, and Microsoft have all publicly announced plans and programs intended to increase diversity in their workforce and in computing generally.

One of Google's stated goals on their diversity portal is "Getting more girls to code" (Google, n.d.). In line with this mission, Google created a website called Made with Code intended to get more girls interested in computing. The first thing a visitor sees when visiting the site is a video where a girl's voice narrates "You are a girl who understands bits exist to be assembled. And when you learn to code, you can assemble anything that you see missing. And in so doing, you will fix something, or change something, or invent something, or run something…"

Visitors to the site can work on a number of projects that show "some of the amazing things you can do with code." By writing code in a block-based programming language similar to Scratch (Resnick et al., 2009), visitors can design a LED dress, make interactive valentines, or take selfies and accessorize them. The projects are united by two things: they are impossible to complete without writing a bit of code, and the project themes and tools are designed to appeal to girls.

CHANGING THE TOOLS

One of the theories underlying Google's Made with Code is that students' attitudes and performance in STEM disciplines are shaped by the design features and affordances of the tools that they use. This phenomenon has been studied for decades in computing. We know that the themes are important to consider when designing educational software. For example, when software contains typically masculine themes like battle and war, girls' performance relative to boys drops. When the software is modified to be more gender-neutral, the gender difference disappears (J. Cooper, 2006; Joel Cooper, Hall, & Huff, 1990; Littleton, Light, Joiner, Messer, & Barnes, 1998).

If themes are important to consider when designing educational software, it makes sense to consider them when designing other educational toolkits as well. And indeed, over the past decade hardware construction kits (i.e., kits targeted at getting novices to build physical artifacts) with feminine themes have begun to emerge. For example, Roominate started as a wired dollhouse marketed to girls that combined playing with dolls with concepts in electricity. It has since grown into a "complete construction set for girls… [where] girls can build anything they can imagine" ("Roominate: A Building Toy for Girls," 2016). Other toolkits on the market that are marketed as ways of getting girls interested in STEM include LittleBits (Bdeir, 2009), the Lilypad Arduino (Buechley & Eisenberg, 2008), and the Adafruit Flora (Stern & Cooper, 2015).

The literature around hardware/electronics construction kits is not nearly as mature as the literature around software, but work in this area seems to indicate that the affordances and design features of construction kits can have similar impacts on youths' attitudes and behavior. What makes the Lilypad Arduino different from other construction kits designed for girls is that it was designed as part of a larger research agenda. This means that there is a growing body of research that both grounds the Lilypad design in theory (Buechley & Eisenberg, 2008; Kafai et al., 2014; Kafai, Peppler, Burke, Moore, & Glosson, 2010; Kafai & Burke, 2014) and explores its impact on children in learning environments (Buchholz et al., 2014; Kafai et al., 2013, 2014; Peppler & Glosson, 2013; Qiu, Buechley, Baafi, & Dubow, 2013). This body of research is nearly unanimous in its declaration that the Lilypad opens up a new pathway for girls to become interested and engaged with computing and engineering.

For example, Buchholz et al. found that when using the Lilypad Arduino, a hardware construction kit designed for creating electronic textiles, girls in mixed-gender dyads spent more time engaged in key practices, and had more opportunities to take on leadership roles (Buchholz, Shively, Peppler, & Wohlwend, 2014). The authors argue that the affordances of the Lilypad Arduino are those that "have historically been valued in feminine communities of practice", and that these cultural affordances "expanded the ways [for girls] into complex electronics and computing content" (p. 18).

The body of work that has arisen around the Lilypad Arduino provides evidence that re-gendering engineering kits to directly appeal to girls is an effective way of increasing interest in computing. The implication is that by shifting young girls' attitudes towards computing at a young age, they will be more inclined to pursue computer science and engineering in their academic and professional careers. However, all of the studies in this arena to date have been observational, and the underlying mechanism responsible for the shift in interest and attitudes is currently unknown. In short, there has been no work directly comparing different tools' impact on students' attitudes and perceptions. This study makes this comparison.

STUDY OVERVIEW AND PROPOSED THEORY

The current study aims to provide a closer examination of the ways that altering the gender valence of construction kits can impact girls' attitudes towards computing. Unlike previous studies that have looked at this phenomenon, the current study leverages an experimental design with two experimental groups and a control group to better tease out the effect of the design of the construction kit on attitudes and identity.

The study took place in a local all-girls middle school during an intersession: a week-long break from normal classes that gives the students an opportunity to learn about non-traditional topics in week-long workshops. N=49 middle-school girls were recruited to take part in a workshop about learning to make things with electronics and programming. The first group—the Sewing and Electronics Workshop (SEW)—used the Adafruit Flora in a workshop called Electric Fashion. The second group—the Workshop Involving Regular Electronics (WIRE)—used a more traditional Arduino Leonardo in a workshop called Light Up Your Life. The third group—the control group—was composed of girls who took part in other workshops offered by the school.

The overall goal of the study was to expose the mechanism through which building projects with different construction kits shifts attitudes towards computing. To achieve this, all of the participants in the study were surveyed before and after the workshop. The surveys measured both implicit attitudes using two Go/No-Go association tests (GNATs) (Nosek & Banaji, 2001) and explicit attitudes towards computing using both novel and pre-existing instruments (Barron, Walter, Martin, & Schatz, 2010; Shaft, Sharfman, & Wu, 2004). The instruments assessed identity, gender stereotypes, general attitudes towards computers, and future career and educational goals. The names of the instruments measuring identity were the Identity GNAT, the Identity Semantic Differential Scale, and the General Identity (Personal and Social) survey. The names of the instruments measuring gender stereotypes were the Gender GNAT and the Gender Semantic Differential Scale. The name of the instrument measuring general attitudes towards computers was the Attitudes Towards Computers Instrument, and the name of the instrument measuring future goals was the Future Career and Educational Goals instrument.

The theorized mechanisms linking the affordances of the tools used in the workshop to the underlying psychological structures are detailed in Figure 2, Figure 3, and Figure 4. The gender valence of the tools used in the workshop is expected to directly impact the girls' social identity related to gender. If the tools used in the workshop are more feminine, as in the SEW group, the girls using those tools should see computing as more feminine (Figure 2). Any shift in the girls' gender stereotypes related to computing should be detectable using the Gender GNAT and Gender Semantic Differential Scale. On the other hand, if the tools used in the workshop are more masculine, as in the WIRE group, the girls using those tools should see computing as more masculine (Figure 3). Again, any shift in the girls' gender stereotypes related to computing should be detectable using the Gender GNAT and Gender Semantic Differential Scale.

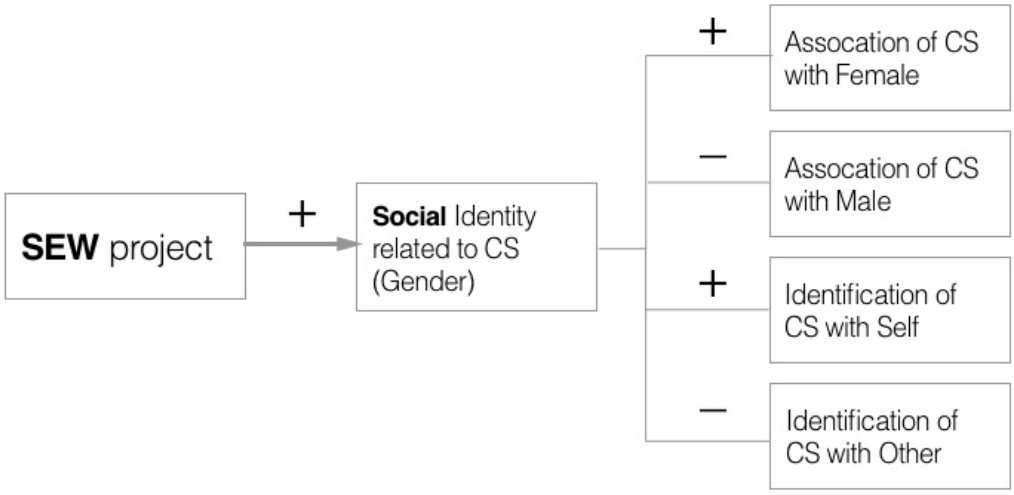

FIGURE 2: THEORIZED LINK BETWEEN SOCIAL (GENDER) IDENTITY AND USING STEREOTYPICALLY FEMALE TOOLS (ADAFRUIT FLORA) AND WORKING ON STEREOTYPICALLY FEMALE PROJECTS (FASHION). BEING IN THE SEW GROUP IS EXPECTED TO INCREASE SOCIAL (GENDER) IDENTITY RELATED TO CS.

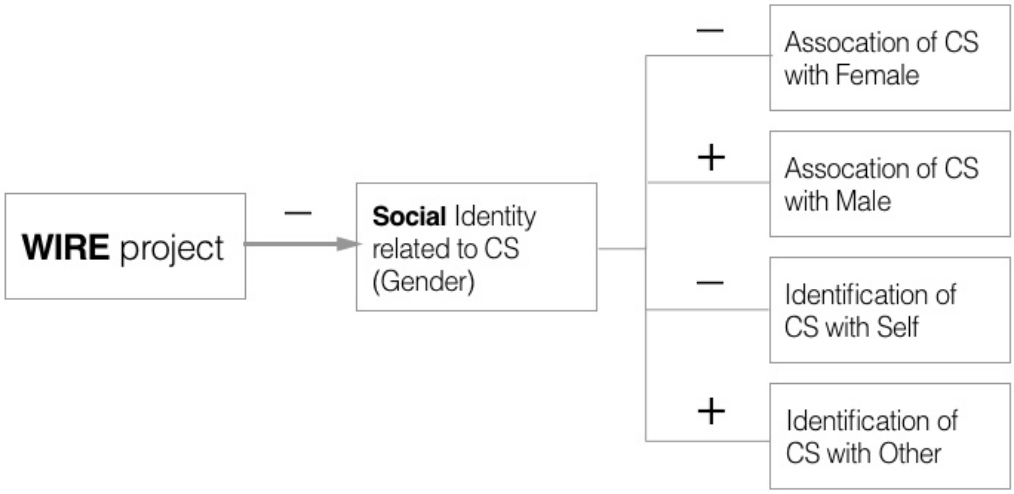

FIGURE 3: THEORIZED LINK BETWEEN SOCIAL (GENDER) IDENTITY AND USING STEREOTYPICALLY MALE TOOLS (ARDUINO LEONARDO). BEING IN THE WIRE GROUP IS THEORIZED TO LOWER SOCIAL (GENDER) IDENTITY RELATED TO CS.

Any shift in the girls' gender stereotypes towards computing should also impact their identification with computing. However, this effect is expected to be weaker than the gender effect for two reasons. First, gender is only one aspect of the girls' identities. This means that even if there is a shift towards associating computing as more feminine, other aspects of the participant's identity unrelated to gender may mute the effect. Second, participation in both the workshops is expected to increase personal identification with computing (Figure 4).

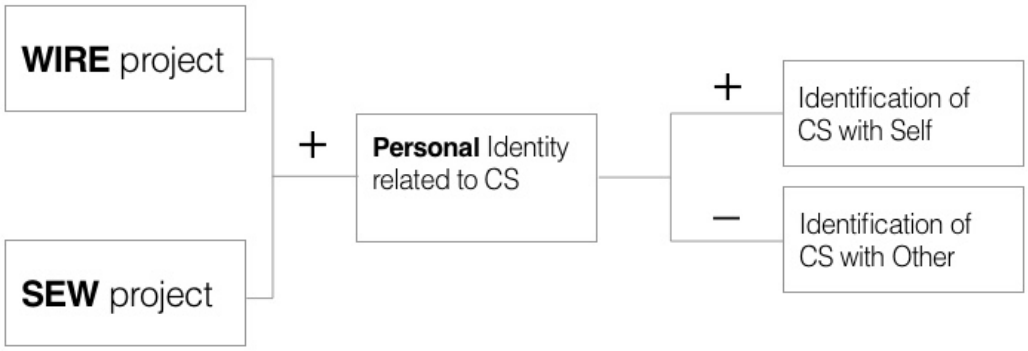

FIGURE 4: THEORIZED LINK BETWEEN PERSONAL IDENTITY AND THE TWO WORKSHOPS. IN BOTH CASES, PERSONAL IDENTITY WITH CS IS EXPECTED TO INCREASE.

RESEARCH QUESTIONS AND HYPOTHESES

1) How did the students' explicit, self-reported attitudes regarding gender perception of computing change as a result of being in the workshop?
   a) According to the theory outlined above, the girls in the SEW group should view computing as more feminine than the Control group post-workshop, and the girls in the WIRE group should see computing as more masculine than the Control group post-workshop.
2) How did the students' implicit attitudes regarding gender perception of computing change as a result of being in the workshop?
   a) The girls in the SEW group should view computing as more feminine than the Control group post-workshop, and the girls in the WIRE group should see computing as more masculine than the Control group post-workshop.
3) How did the students' explicit, self-reported attitudes regarding identification with computing change as a result of being in the workshop?
   a) Both the SEW and WIRE groups should identify more strongly with computing after the workshop. When comparing the SEW and WIRE groups directly, the SEW group should identify more strongly with computing than the WIRE group.
4) How did the students' implicit attitudes regarding identification with computing change as a result of being in the workshop?
   a) Both the SEW and WIRE groups should identify more strongly with computing after the workshop. When comparing the SEW and WIRE groups directly, the SEW group should identify more strongly with computing than the WIRE group.
5) How did the workshop impact students' general attitudes towards computing?
   a) If the participants identify more strongly with computing after the workshop, their attitudes towards computing should increase.
6) How did the workshop impact students' general identity?
   a) If the participants identify more strongly with computing on the other measures, their identification with computing should increase on this measure as well.
7) How did the workshop impact students' future career and educational goals?
   a) It is unlikely that a week-long workshop will impact the participants' future career goals, but it may have a positive impact on their educational goals.

METHODS AND PARTICIPANTS

PARTICIPANTS

6th and 8th grade girls were recruited from an all-girls middle school in Silicon Valley (N=46 6th graders, N=3 8th graders). The school is notable in that computer science is one of the core subjects, so all of the students had some limited prior programming experience with Scratch. Our study was conducted during a week long intersession where classes were suspended and all the students in 6th and 8th grades took part in a variety of workshops and electives. Choices included workshops in stop animation, reading Harry Potter and discussing its contents, outdoor survival, learning about and drinking tea, learning about India culture and cuisine, working on the yearbook, set design, quilting, Latino culture in the Bay area, sailing, and others. Ours were the only workshops where students learned about electronics and computer programming.

I designed two week-long workshops that both took place during the intersession. The first workshop, titled Electric Fashion, introduced the girls to programming microcontrollers with electronic textiles. We introduced the girls to programming using the Adafruit Flora—a sewable Arduino microcontroller—and a variety of sewable LEDs and sensors. This group of girls is referred to as the SEW group (Sewing and Electronics Workshop) in this paper. The second workshop, titled Light Up Your Life, covered the same conceptual content as the first workshop, but used a different programmable microcontroller. Instead of a sewable microcontroller, this group used an Arduino Leonardo. And instead of using conductive thread to connect the sensors and LEDs, the students in Light Up Your Life used wires, solder, and breadboards. This group of girls is referred to as the WIRE group (Workshop Involving Regular Electronics) in this paper.

Out of the 49 students who took part in our study, N=20 were selected by the school administration to take part in our workshops and N=29 were selected to be in the control group. The administration stated that the assignments were random, however I was not part of the randomization or selection process. Students in the control group took part in a variety of different workshops unrelated to electronics and programming, but still took the pre- and post-surveys. N=10 (9 6th graders) students were assigned to the Electric Fashion workshop, and the other N=10 (8 6th graders) were assigned to the Light Up Your Life workshop.

MATERIALS

HARDWARE

Students in the SEW group learned to program the Adafruit Flora, a microcontroller that can be sewn into fabric and other soft materials (Figure 5). The Flora is compatible with a number of sewable sensors (e.g., a light sensor, a motion sensor) and actuators (e.g., sewable LEDs). These components can be connected by sewing them together using stainless steel conductive thread to complete a complete, responsive, programmable system. For example, the Flora can be connected to a light sensor and an LED using conductive thread, then programmed to turn the LED on when the light sensor reports darkness.

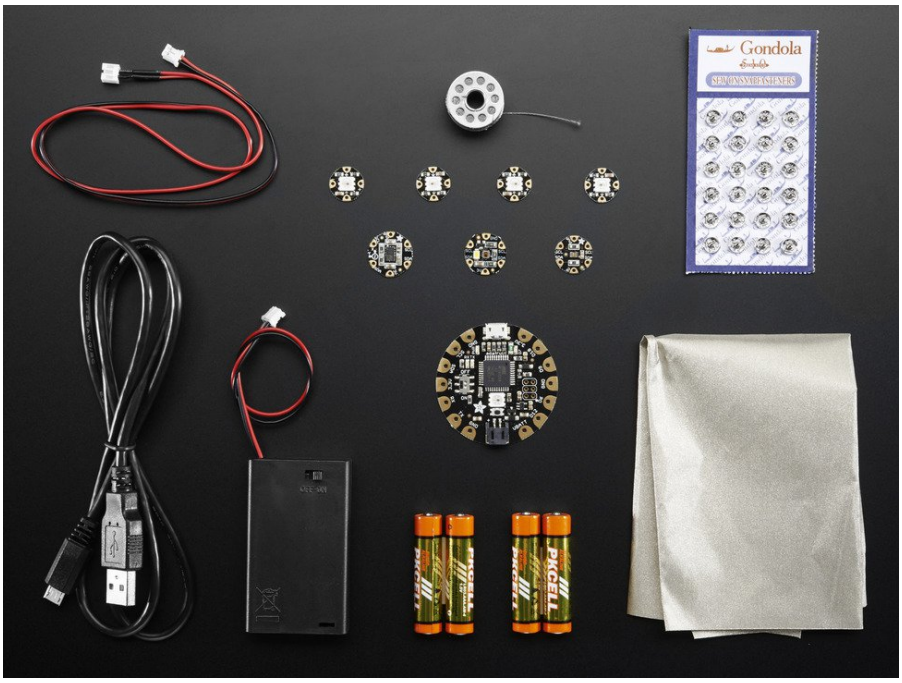

FIGURE 5: MATERIALS USED IN THE SEW GROUP. CONDUCTIVE THREAD, SEWABLE LEDS, LIGHT SENSOR, COLOR SENSOR, ACCELEROMETER, SNAPS, CONDUCTIVE FABRIC, AND (CENTER) ADAFRUIT FLORA

Students in the WIRE group learned to program the Arduino Leonardo. Both the Flora and Micro use the same microcontroller, the ATmega 32u4 (Figure 6). This means that a program written for the Flora can be downloaded to the Micro and the functionality will be identical. However, the Arduino Leonardo is not designed to be sewn into soft materials using conductive thread. Instead, the Leonardo is the latest in a long line of hobbyist microcontrollers (stretching back to the BASIC Stamp, released in 1992) to use wire, breadboards, and soldering as the primary connection method. The full list of sensors and actuators provided for each group is reported in Table 1 below.

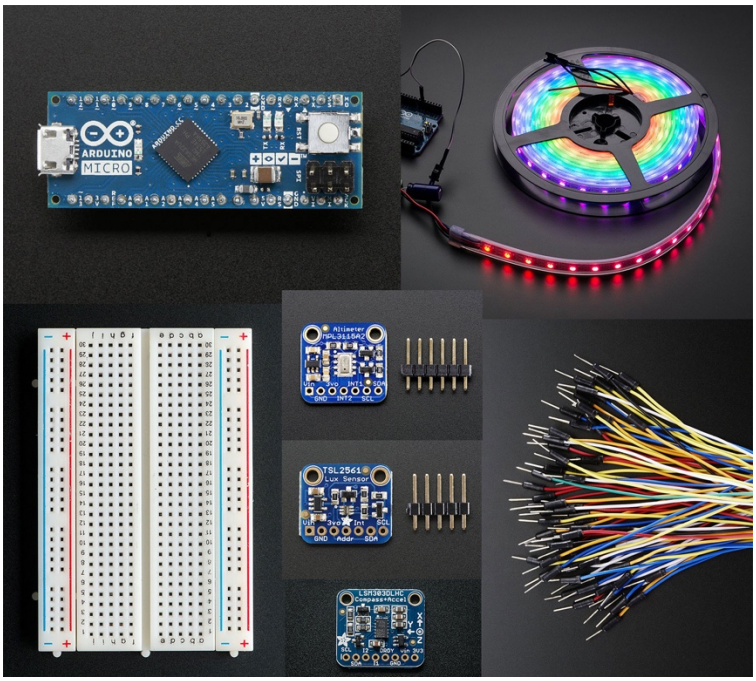

FIGURE 6: MATERIALS USED IN THE WIRE GROUP. CLOCKWISE FROM TOP-LEFT: ARDUINO LEONARDO, LED STRIP, WIRES, PRESSURE SENSOR, LIGHT SENSOR, ACCELEROMETER, AND BREADBOARD

	SEW Group	WIRE Group
Microcontroller	Adafruit Flora	Arduino Leonardo
Sensors (Inputs)	Color Sensor, Accelerometer, Compass, Light Sensor	Accelerometer, Compass, Light Sensor, Pressure Sensor, Temperature Sensor,
Actuators (Outputs)	Sewable LEDs, LED Strip	LED Strip
Miscellaneous Items	Conductive Fabric, Conductive Thread, Alligator Clips	Breadboard, Wires, Solder and Soldering Iron, Wire Strippers

TABLE 1: COMPARISON OF MICROCONTROLLERS AND ELECTRONICS USED IN EACH WORKSHOP

SOFTWARE

While the Arduino programming environment does simplify many of the difficult parts of physical computing, it may not be the ideal environment for middle-school students' first exposure to physical computing (Sadler, Shluzas, & Blikstein, 2016). Because the participants were all learning the Scratch programming language (Resnick et al., 2009) as part of their core curriculum, a member of our research team created a set of tools that allowed the girls to use the Scratch programming language to program their microcontrollers. The first tool was a hardware simulator built entirely in Scratch that provided a way to light up virtual LEDs, read input from virtual sensors, and connect the virtual sensors and virtual

LEDs using code. The second tool was a Scratch to Arduino translator that provided a way to convert the programs written for the Scratch hardware simulator to code that would run on the actual hardware. The Scratch to Arduino translator also logged each program that it converted. The analysis of this code is ongoing and not included in this report.

INSTRUMENTS

In order to understand the girls' attitudes a set of instruments were administered before and after the workshop. The data collected with these instruments made it possible to get a better picture of the girls' attitudes before the workshops, and to see how their attitudes changed as a result of being in either the SEW, WIRE, or control groups. The attitudes measured were personal identification with computer science, personal identification with arts, gender stereotypes of computer science, gender stereotypes of arts, cognitive attitudes towards computing, affective attitudes towards computing, and future goals related to computing. The hope in collecting data related to these attitudes was to gain a more nuanced understanding of how gender stereotypes and personal identity were related, how gender stereotypes and personal identity might change as a result of being in the SEW or WIRE groups, and how shifts in those sets of attitudes might impact future goals, cognitive, and affective attitudes towards computing.

Traditionally, self-report measures have been used to assess students' attitudes towards computing and gender. However, explicit responses can be biased due to self-presentation (distorting attitudes due to social or personal pressure). For this reason, implicit measures of attitudes were included in the study. The implicit tests measured the subset of explicit attitudes that were most vulnerable to self-presentation bias: gender stereotypes and self-identification with computing and arts.

IMPLICIT ATTITUDES: GENDER STEREOTYPES AND PERSONAL IDENTITY

The Go/No-Go Association Test (GNAT) assesses the strength of an association between a target category (e.g., computing) and two poles of an attribute dimension (e.g., male-female) (Nosek & Banaji, 2001). During the GNAT procedure, stimuli from the target category and from one pole of the attribute dimension are the signal or go items, which stimuli that do not match the target category or the target pole of the attribute dimension serve as noise or no-go items. A correct response on a go trial requires pressing the space bar on a computer keyboard to correctly identify the stimulus as belonging to the target attribute or attribute dimension.

For example, a participant might be asked to correctly identify stimuli that are either related to computing (the target category) or feminine (the attribute dimension). On the first trial, the word "Internet" appears on the screen and the participant hits the space button—a correct response—and sees a green check mark. On the next trial, the word "Boy" appears on the screen and the participant hits the space bar—an incorrect response—and sees a red circle. Finally, the word "Sewing" appears on the screen and the participant does not hit the space bar. After 833 milliseconds, a green check mark appears on the screen (see Figure 7 for an example trial).

FIGURE 7: EXAMPLE GNAT. ON THE TOP-LEFT IS THE TARGET CONCEPT (ARTS) AND ON THE TOP-RIGHT IS THE TARGET ATTRIBUTE (MASCULINE). WHEN STIMULI THAT MATCH EITHER OF THESE SIGNAL CATEGORIES ARE PRESENTED, A CORRECT RESPONSE WAS TO HIT THE SPACEBAR BEFORE THE DEADLINE. A CORRECT RESPONSE WAS INDICATED BY A GREEN CIRCLE.

I designed two GNATs to measure the strengths of eight different associations. The Gender GNAT measured the associations between female and computing, male and computing, female and arts, and male and arts (Table 2). The Identity GNAT measured the associations between self and computing, other and computing, self and arts, and other and arts (Table 3). Both GNATs were created on the Inquisit Millisecond platform and administered online using the Inquisit Millisecond Web Player (Draine, 1998).

Gender GNAT	Category	Stimuli
Target A	Computing	Artificial intelligence, programming, computers, robotics, coding, Arduino, algorithms, debugging, electronics, Scratch
Target B	Arts	Pottery, sewing, drawing, sketching, arts, stencils, quilting, painting, crafts, knitting, jewelry
Attribute A	Female	Female, feminine, girl, woman, her, she, hers
Attribute B	Male	Male, masculine, boy, man, him, he, his

TABLE 2: GENDER GNAT TARGETS, ATTRIBUTES, AND STIMULI

Identity GNAT	Category	Stimuli
Target A	Computing	Artificial intelligence, programming, computers, robotics, coding, Arduino, algorithms, debugging, electronics, Scratch
Target B	Arts	Pottery, sewing, drawing, sketching, arts, stencils, quilting, painting, crafts, knitting, jewelry
Attribute A	Self	Myself, me, mine, I, self, my
Attribute B	Other	Someone else, them, other, not me, they

TABLE 3: IDENTITY GNAT TARGETS, ATTRIBUTES, AND STIMULI

Each GNAT consisted of 12 blocks. In blocks 1-4, participants sorted stimuli into a single target (e.g., computing) or attribute (e.g., female) that served as a signal item. The signal item was presented as a word at the top of the screen for the duration of the block. The purpose of the first four blocks was to familiarize the participants with the test procedure, as well as with the targets, attributes, and stimuli. The response deadline for each trial in these blocks was one second, and 20 trials were presented in each block. During each trial, a stimulus word was randomly chosen and presented to the participant in the center of the screen. If the word matched the target category (e.g., boy and masculine), the correct response was to hit the spacebar before the response deadline timed out. If the word did not match the target category (e.g., girl and feminine), the correct response was to wait for the response deadline to time out. 10 of the stimuli were signal items, and 10 were distractors. The stimuli order and block order were randomized for each participant.

In blocks 5-8 two signal items were presented as words at the top-left and top-right of the screen. One of the signal items was a target concept (e.g., computing or arts) and the other was an attribute item (e.g., female or male). Each block presented a unique Target/Attribute combination. The response deadline for each trial in these blocks was 833 milliseconds, and 66 trials were presented in each block. The first 16 trials trained participants on the new target/attribute combination. In following 50 trials, a stimulus word was randomly chosen and presented to the participant in the center of the screen. If the word matched the target category or attribute, the correct response was to hit the spacebar before the response deadline timed out. If the word did not match the target category or attribute, the correct response was to wait for the response deadline to time out. 25 of the stimuli were signal items, and 25 were distractors. The stimuli order and block order were randomized for each participant.

Blocks 9-12 were the same as blocks 5-8 with a single difference: the response deadline was changed from 833 milliseconds to 666 milliseconds. The point of the response deadline in the GNAT is to increase time pressure, causing an increase the difference between signal and noise in the data. The 666 millisecond response deadline was used in case the 833 millisecond response deadline was not difficult enough to force separation between signal and noise. For a summary of the GNAT design see Table 4.

	Number of Trials	Response Deadline	Signal
Blocks 1-4	20	1000 ms	Single target or attribute
Blocks 5-8	66	833 ms	Target, Attribute pair
Blocks 9-12	66	666 ms	Target, Attribute pair

TABLE 4: FULL GNAT DESIGN

As recommended by the creators of the GNAT, d-prime was used as a measure of the strength of the participants' association between the two target concepts (Nosek & Banaji, 2001). To calculate d-prime, first the proportion of hits was calculated by dividing the number of correct 'go' responses (correctly hitting the spacebar for stimulus items that matched one of the two target categories) by the total number of signal trials. Next, the proportion of misses was calculated by dividing the number of incorrect 'go' responses (wrongly hitting the spacebar) by the total number of distractor trials. Finally, each of these proportions was converted into a z-score and subtracted from one another. The resulting value is d-prime. The larger the value of d-prime, the stronger the association between the two target concepts.

EXPLICIT ATTITUDES: GENDER STEREOTYPES AND PERSONAL IDENTITY

As a complement to the Gender GNAT and Identity GNAT, I designed two 11-point semantic differential scales. The surveys were created on the Qualtrics platform and administered online. The Gender Semantic Differential Scale measured the girls' explicit attitudes regarding gender, computing, and arts. The Identity Semantic Differential Scale measured the girls' explicit attitudes regarding personal identity, computing, and arts. In a semantic differential scale, participants are presented with a set of attitude objects and asked to rate each of them along a bipolar adjective scale (Osgood, 1952). For example, on the Gender Semantic Differential Scale participants rate words like "programming", "Scratch", "sewing", and "Arduino" from 0 (masculine) to 10 (feminine) (Figure 8). On the Identity Semantic Differential Scale, they would rate the same items from 0 (Not My Kind of Thing) to 10 (My Kind of Thing or Could Be My Kind of Thing). The same 30 attitude objects were presented in both scales. The order of the questions was randomized.

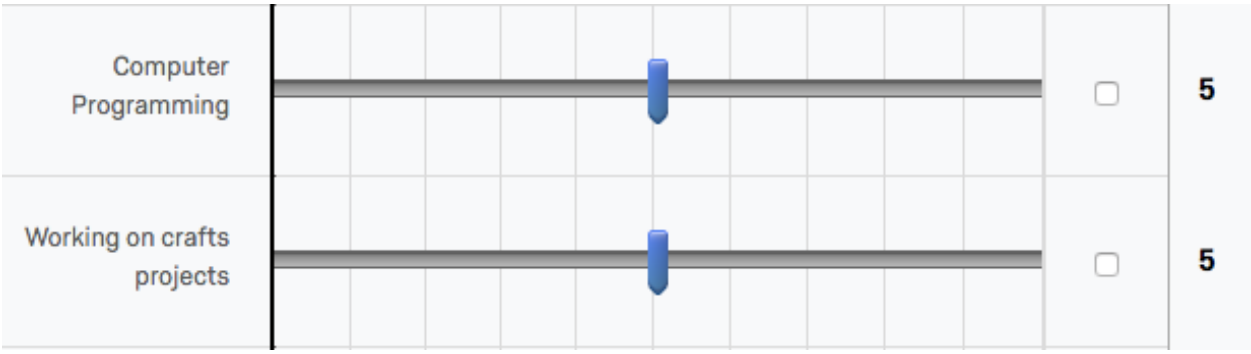

FIGURE 8: TWO EXAMPLE ITEMS FROM THE SEMANTIC DIFFERENTIAL SCALE

EXPLICIT ATTITUDES: GENERAL ATTITUDES TOWARDS COMPUTERS

The participants' general attitudes towards computers was measured using the Attitudes Towards Computing Instrument (ATCI) (Shaft, Sharfman, & Wu, 2004). The ATCI is a seven-question semantic differential scale that measures cognitive, affective, and behavioral attitudes towards computers. Each of these attitudes is theorized to be part of a more general attitude construct, meaning that the ATCI should measure a single underlying factor. This was confirmed by the survey designers using confirmatory factory analysis. The order of the questions was randomized.

Cognitive	Computers…	Restrain/Enhance Creatvity
Affective	Computers are…	Helpful/Harmful
Behavioral	Computers…	Decrease/Increase Productivity

TABLE 5: EXAMPLE QUESTIONS FROM THE ATTITUDES TOWARDS COMPUTERS INSTRUMENT (ATCI)

EXPLICIT ATTITUDES: GENERAL IDENTITY (PERSONAL AND SOCIAL)

The General Identity (Personal and Social) survey was adapted from the Access, Interest, and Experience survey (Barron, Walter, Martin, & Schatz, 2010; Tellez, 2013). It is composed of 16 questions that ask the participant to describe their personal identification with computing, their interest in learning more about computing, and whether it is important to their friends, family, and teachers if they know about computers. Each of the questions can be answered on a 7-item Likert scale. For example, one question asks participants to rate if they would like to learn more about computers from strongly agree (coded 7) or strongly disagree (coded 1).

EXPLICIT ATTITUDES: FUTURE CAREER AND EDUCATIONAL GOALS

The Future Career and Educational Goals survey was adapted from the Access, Interest, and Experience survey (Barron et al., 2010; Tellez, 2013). It is composed of 26 questions that ask the participant to rate their future career goals (e.g., becoming a computer programmer) and their future educational goals (e.g., learning more about hardware) on a 7-item Likert scale. The possible answers range from "Definitely no" (1) to "Definitely yes" (7). Because this survey asks about intentions to pursue different classes, majors, and careers, it be thought of as a measure of participants' behavioral attitudes towards computing.

DESIGN

N=49 middle-school girls were recruited to take part in the study. The study took place in a Silicon Valley all-girls middle school during a week-long intersession. During this intersession all classes were suspended and the 6th and 8th grade girls chose from a number of different week-long workshop opportunities. I offered two different workshops during the intersession. The first workshop—the Sewing and Electronics Workshop (SEW)—used the Adafruit Flora in a workshop called Electric Fashion. The second group—the Workshop Involving Regular Electronics (WIRE)—used a more traditional Arduino

Leonardo in a workshop called Light Up Your Life. The third group—the control group—was composed of girls who took part in other workshops offered by the school (Table 6).

Participants	Pre-Surveys (30 min)	Treatment	Post-Surveys (30 min)
SEW Group (N=10)	Implicit and Explicit Attitudes	Electric Fashion: create fashion projects with electronic textiles	Implicit and Explicit Attitudes
WIRE Group (N=10)	Implicit and Explicit Attitudes	Light Up Your Life: Make everyday objects interactive	Implicit and Explicit Attitudes
Control Group (N=29)	Implicit and Explicit Attitudes	None	Implicit and Explicit Attitudes

TABLE 6: STUDY DESIGN

N=10 girls were assigned by the school into the SEW group, N=10 girls were assigned by the school into the WIRE group, and N=29 girls were assigned by the school into the control group. I requested that the school randomly assign girls into the workshops, however it was not possible to confirm that random assignment did occur.

Girls in the SEW group learned how to program and create electronic textiles projects using the Adafruit Flora. Girls in the WIRE group learned how the program and create more traditional electronics projects using the Arduino Leonardo. Girls in the control group took part in a number of different workshops that were offered by the school unrelated to programming and electronics. The girls in the SEW and WIRE groups used the same software to program their projects, and were taught using the same materials (with slight changes to account for the differences in the hardware). Every attempt was made to control the software and instructional content between the two workshops so that the effects of the hardware design on the girls' attitudes could be isolated.

The surveys were administered two times: once at the start of the week and once at the end of the week. The girls in the SEW and WIRE groups took the implicit and explicit attitudes surveys on Monday at the start of the intersession and again on Friday at the end of the intersession. The girls in the control group took the implicit and explicit surveys twice as well: first on the Monday that followed the intersession week, and again on the Friday that followed the intersession week. All code that passed through the Scratch to Arduino translator was captured as well.

PROCEDURE

SURVEYS

The workshops took place in the science classroom of the middle school. The surveys for the SEW and WIRE groups were administered in the science classroom at the start and end of the workshop. The surveys were digital, delivered through the Inquisit and Qualtrics platforms (Draine, 1998), and the girls took the surveys on their personal laptops. The full set of surveys took roughly 45 minutes to complete.

WORKSHOP SCHEDULE

The girls in the SEW and WIRE groups followed identical instructional schedules. On the first day, the girls took the pre-surveys and were given their construction kits and introduced to the programming environment. The bulk of the first day was spent learning how to light up the digital LEDs in the Scratch simulator. On the second day the girls were introduced to the concept of sensors. They spent the part of the day learning how to integrate the sensors and LEDs in the Scratch simulator, and part of the day brainstorming ideas for their projects. On the third day, the girls moved from working in the Scratch simulator to working with their electronics kits. Part of the day was spent learning how to use the Scratch-to-Arduino translator to convert simulated programs to programs that ran on the hardware, and part of the day was spent brainstorming and presenting their project ideas to the class. The fourth day of the workshop was a work day: the girls spent the entire day working on their projects with the help of the facilitators. On the final day, the girls took post-surveys and wrapped up their projects. At the end of the final day the girls presented their projects at an assembly in front of the entire school.

RESULTS

OVERVIEW

The results below are broken into two broad categories: implicit attitudes and explicit attitudes. The implicit surveys measure automatic, non-conscious associations between the target categories (computing, arts) and the test-specific attributes (gender, identity). In contrast to the implicit surveys, the explicit attitudes surveys measure the conscious attitudes and self-concepts of the participants. The explicit surveys measure the participants' self-concept related to computing and art, their gender stereotypes related to computing and art, their general attitudes towards computing, their general attitudes towards themselves, and future career and educational goals.

Two distinct types of analysis were performed for each instrument in the study. The first analysis is mostly descriptive, while the second analysis is mostly inferential. These labels (descriptive and inferential) will be used to differentiate the two analyses even though they do not apply perfectly. The descriptive analyses were performed on the pooled pre-survey data collected from all of the experimental groups (N=49). The goal of the descriptive statistical analysis was to gain a better understanding of the girls' attitudes unrelated to the experiment. The inferential analysis was performed to better understand how taking part in either the SEW, WIRE, or control group changed the participants' attitudes.

IMPLICIT ATTITUDES

The two implicit attitudes surveys were designed to measure the participants' implicit attitudes towards gender, engineering, and arts; and identity, engineering, and arts. Both of the surveys were Go/No-go association tasks (GNAT). The strength of the association between the target concept and attribute is given by d-prime. d-prime is a measure of the separation between the means of the signal and the noise distributions in the data. It is the standardized difference between the mean of the signal and the mean of the noise. The higher the d-prime, the easier it was for the participant to associate the target concept and attribute.

d-prime values of zero indicate that the participant was unable to identify the signal at all. d-prime values below zero indicate that the participant was better at selecting the noise than the signal in that trial and most likely confused. In accordance with the advice of the GNAT designers, all values of d-prime below zero were removed before analysis.

Each GNAT collected the same set of data twice, only at different response deadlines. Blocks 5-9 used a response deadline of 833 milliseconds, and blocks 10-14 used a response deadline of 666 milliseconds. These times were estimated to be correct based on previous studies using the GNAT (Nosek & Banaji, 2001). However, blocks 10-14 were found to have abnormally high error rates, so they are not included in the analysis.

DESCRIPTIVE ANALYSIS OF PRE-SCORES: GENDER GNAT

The overall findings from the descriptive analysis of gender can be summed up simply: the middle-school girls implicitly associate computing with men and arts with women. A plot of the mean d-prime scores on each of the blocks in the Gender GNAT can be found in Figure 9.

A number of significant differences were discovered when looking at the pooled data from the girls' pre-survey responses. The girls were more likely to associate computing with male (mean=1.41, sd=0.88) than with female (mean =1.08, sd=0.86); $t(42) = 2.28$, $p < 0.03$. The girls were also more likely to associate arts with female (mean=1.49, sd=0.82) than with male (mean=0.78, sd=0.70); $t(43) = -6.15$, $p < 10^{-6}$. In other words, the girls' automatic associations were in line with common stereotypes about computing, arts, and gender.

In addition to this, the girls were more likely to associate arts with female (mean=1.49, sd=0.82) than computing with female (mean=1.06, sd=0.86); $t(43) = -2.84$, $p < 0.01$. The girls were also more likely to associate computing with male (mean=1.41, sd=0.88) than arts with male (mean=0.78, sd=0.70); $t(42) = 5.01$, $p < 10^{-4}$. Again, this is evidence that the girls' automatic associations were in line with common stereotypes.

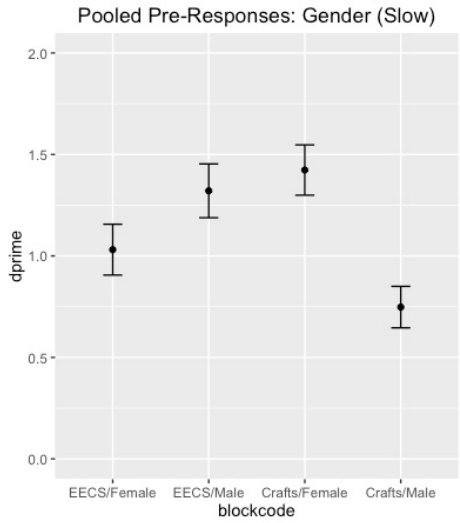

FIGURE 9: MEAN D-PRIME VALUES OF POOLED PRE-RESPONSES ON THE GENDER GNAT. ERROR BARS SHOW STANDARD ERROR

DESCRIPTIVE ANALYSIS OF PRE-SCORES: IDENTITY GNAT

The overall findings from the descriptive analysis of identity are that the girls identify themselves with computing as much as they associate others with computing. They are also more likely to associate themselves with arts than they are to associate others with arts. A plot of the mean d-prime scores on each of the blocks in the Identity GNAT can be found in Figure 10.

An analysis of the pooled data from the pre-survey responses on the Identity GNAT shows that the girls were more likely to associate arts with self (mean=1.00, sd=sd=0.97) than with other (mean=0.73, sd=0.77); $t(43) = 2.26$, $p < 0.03$. However, no significant difference was detected between the mean d-prime values for self and computing (mean=0.86, sd=0.76) and other and computing (mean=0.86, sd=0.76); $t(43) = 0.98$, $p < 0.34$.

Furthermore, the girls were more likely to associate computing with others (mean=0.87, sd=0.76) than arts with others (mean=0.73, sd=0.70); $t(43) = 2.04$, $p < 0.05$. There was no difference detected between the association of self and computing (mean=0.98, sd=0.78) and self and arts (mean=1.00, sd=0.97); $t(43) = -0.69$, $p < 0.50$.

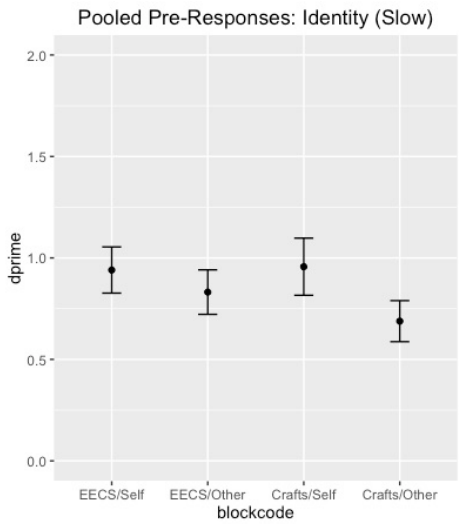

FIGURE 10: MEAN D-PRIME VALUES OF POOLED PRE-RESPONSES ON THE IDENTITY GNAT. ERROR BARS SHOW STANDARD ERROR.

INFERENTIAL ANALYSIS: GENDER GNAT OVERVIEW

When controlling for pre-workshop scores, girls in the WIRE group had higher d-prime scores than the control group when associating male and computing and male and arts. No significant effects were found for the SEW group.

To determine these effects, I performed two multiple regression analyses on each block. The first analysis was equivalent to a one-way ANCOVA. The independent variable, workshop, involved three levels: WIRE, SEW, or Control. The dependent variable was the post-workshop d-prime score and the covariate was the pre-workshop d-prime score. The second analysis included the interaction between workshop and pre-workshop d-prime score. The covariates were centered in all analyses.

The results of each analysis are presented in a regression table. The results of the ANCOVA are reported in the first column labeled ANCOVA, and the results of the second analysis are reported in the second column labeled GLM (for Generalized Linear Model). Because the covariates were centered, the coefficient of the Intercept is the mean post-test score for the control group. The mean post-test d-prime

for the SEW group can be found by adding the SEW coefficient to the value of the Intercept. The same procedure can be used to find the mean post-test d-prime for the WIRE group. A significant interaction means that the assumptions of the ANCOVA were violated, and in those cases I will attempt to provide an interpretation of the interaction.

ASSOCIATION BETWEEN MALE AND COMPUTING

After the workshop, the WIRE group was more likely to associate male and computing than the control group. This was indicated by a significant difference in the post-workshop d-prime scores for the WIRE group when compared to the post-workshop d-prime scores for the Control group. No significant difference was detected between the SEW group and the Control group.

	ANCOVA	GLM
Intercept	1.27^{***}	1.26^{***}
	(0.19)	(0.19)
Pre(Centered)	$0.27^{\cdot}$	0.09
	(0.15)	(0.18)
SEW	0.44	0.30
	(0.39)	(0.40)
WIRE	0.87^{*}	$0.76^{\cdot}$
	(0.42)	(0.42)
Pre(Centered)*SEW		0.62
		(0.44)
Pre(Centered)*WIRE		0.56
		(0.40)
R^2	0.23	0.31
Adj. R^2	0.16	0.19
Num. obs.	35	35
RMSE	0.90	0.88

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

TABLE 7: IMPLICIT ASSOCIATION BETWEEN MALE AND COMPUTING

ASSOCIATION BETWEEN FEMALE AND COMPUTING

No difference was detected for either workshop group on post-workshop d-prime scores.

ASSOCIATION BETWEEN MALE AND ARTS

After the workshop, the WIRE group was more likely to associate male and arts than the control group. This was indicated by a significant difference in the post-workshop d-prime scores for the WIRE group when compared to the post-workshop d-prime scores for the Control group. A trending difference in the same direction was detected between the SEW group and the Control group ($p < 0.14$).

	ANCOVA	GLM
Intercept	0.69***	0.68***
	(0.15)	(0.15)
Pre(Centered)	0.08	0.01
	(0.13)	(0.16)
SEW	0.43	0.44
	(0.28)	(0.29)
WIRE	1.23**	1.09*
	(0.35)	(0.40)
Pre(Centered)*SEW		0.11
		(0.39)
Pre(Centered)*WIRE		0.29
		(0.34)
R^2	0.35	0.37
Adj. R^2	0.28	0.25
Num. obs.	33	33
RMSE	0.67	0.68

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

TABLE 8: IMPLICIT ASSOCIATION BETWEEN MALE AND ARTS

ASSOCIATION BETWEEN FEMALE AND ARTS

No difference was detected for either workshop group on post-workshop d-prime scores.

INFERENTIAL ANALYSIS: IDENTITY GNAT OVERVIEW

When controlling for pre-workshop scores, girls in the SEW group were less likely to associate computing with other than the control or WIRE group. Compared to the WIRE and Control groups, the girls in the SEW group had lower d-prime scores. Another way of phrasing this is that the girls in the WIRE group were significantly more likely to associate computing with other than the girls in the SEW group.

To determine these effects, I performed the same set of analyses as in the Gender GNAT: two multiple regression analyses on each block. The results are presented in the same format.

ASSOCIATION BETWEEN SELF AND COMPUTING

No difference was detected for either workshop group on post-workshop d-prime scores.

ASSOCIATION BETWEEN OTHER AND COMPUTING

After the workshop, the SEW group was less likely to associate other and computing than the control group or the WIRE group. This was indicated by a nearly significant difference in the post-workshop d-prime scores for the SEW group when compared to the post-workshop d-prime scores for the Control group.

	ANCOVA	GLM
Intercept	1.34^{***}	1.34^{***}
	(0.17)	(0.17)
Pre(Centered)	$0.24^{\cdot}$	0.21
	(0.13)	(0.19)
SEW	$-0.61^{\cdot}$	-0.61
	(0.32)	(0.36)
WIRE	0.42	0.40
	(0.34)	(0.35)
Pre(Centered)*SEW		0.02
		(0.34)
Pre(Centered)*WIRE		0.08
		(0.30)
R^2	0.26	0.27
Adj. R^2	0.18	0.12
Num. obs.	31	31
RMSE	0.71	0.74

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

TABLE 9: IMPLICIT ASSOCIATION BETWEEN OTHER AND COMPUTING

ASSOCIATION BETWEEN SELF AND ARTS AND CRAFTS

No difference was detected for either workshop group on post-workshop d-prime scores.

ASSOCIATION BETWEEN OTHER AND ARTS AND CRAFTS

No difference was detected for either workshop group on post-workshop d-prime scores.

EXPLICIT ATTITUDES

The participants' explicit attitudes and identities related to computing and arts were measured with five different instruments. Two of the instruments—the Gender Semantic Differential Scale and the Identity Differential Scale—were designed to provide parallel, explicit measures to complement the Gender GNAT and Identity GNAT. The third instrument—the Attitudes Towards Computing Instrument (ATCI)—measures general attitudes towards computers. The fourth instrument—General Identity—was adapted from the Access, Interest, and Experience survey (Barron et al., 2010; Tellez, 2013), and designed to measure the participants personal identification with computing, their interest in learning more about computing, and whether it is important to their friends, family, and teachers if they know about computers. The fifth and final instrument—Future Career and Educational Goals—was also adapted from the Access, Interest, and Experience survey, and was designed to learn more about the participants' future academic and career goals.

Because of the large number of questions on these five instruments, it was necessary to group questions to reduce the number of statistical tests and lower the threat of Type 1 error. An exploratory principal components analysis (PCA) was performed on each instrument to determine the number of latent factors that each instrument was measuring. To perform the PCA, I combined the pre-workshop data from all the participants in the study, collapsing across experimental condition. The resulting data

contained pre-survey responses from N=49 students. The number of underlying principal components was determined using a chi-square goodness of fit with an alpha > 0.05 indicating the correct number of principal components needed to fit the data. A cut of value of 0.4 was used to determine which questions loaded onto each principal component. Cohen's alpha was used to determine the stability of each principal component. Finally, the questions in each principal component were averaged to give an index of the underlying factor.

DESCRIPTIVE ANALYSIS OF PRE-SCORES: GENDER SEMANTIC DIFFERENTIAL SCALE

The Gender Semantic Differential Scale is a 36-question survey that measures the participants' gender stereotypes on a set of attitude objects. Each item is rated on a scale from masculine (0) to feminine (10). For example, one question asks participants to rate "Making projects with computers" as either masculine (coded 0) or feminine (coded 10). The further the slider is pushed towards 10, the more feminine the participant perceives the item. I created the Gender Semantic Differential Scale to complement to the Gender GNAT. While the Gender GNAT is intended to measure implicit attitudes towards computing and arts, the Gender Semantic Differential Scale is intended to measure the participants' explicit attitudes on a similar set of items.

I initially intended the Gender Semantic Differential Scale to measure two latent factors: explicit attitudes towards computing and explicit attitudes towards arts. However, a chi-square goodness of fit rejected the hypothesis that two principal components were sufficient to fit the data. The chi-square goodness of fit only failed to reject the hypothesis that five principal components were sufficient to fit the data. In other words, five principal components were necessary to capture the variability in the responses. Initial eigenvalues indicated that the first five principal components explained 22%, 15%, 14%, 08%, and 10% of the variance respectively. These five principal components are summarized in Table 10.

Principal Component	Description	Number of Questions that Load onto Factor	Variance Explained	Cohen's Alpha
1	Electronics vs. Arts and Crafts	15	0.22	0.92
2	Programming	11	0.15	0.87
3	Makeup, fashion, smartphones, LEDs	9	0.14	0.86
4	Items in the workshop	5	0.08	0.6
5	Arts and Sciences	8	0.10	0.82

TABLE 10: LATENT FACTORS IN THE GENDER SLIDERS SURVEY

A plot of the pooled pre-workshop responses to the Gender Semantic Differential Scale can be found in Figure 11. Interestingly, the girls' explicit gender stereotypes parallel their implicit stereotypes on similar measures. Words like "sewing", "fashion", "art class", and "painting" are seen as more feminine, while words like "electronic test equipment", "writing code", and "computer hacking" are seen as more masculine. However, most of the items on this scale are most commonly rated 5, or neutral.

In order to compare the girls' explicit attitudes to their implicit attitudes, I matched items from the Gender Semantic Differential Scale to items presented in the Gender GNAT and created two categories: Computing and Arts. A paired t-test showed that the girls were more likely to rate the computing questions as more masculine (mean=6.23, sd=1.06) than the arts questions (mean=4.79, sd=0.46); $t(31)=-6.434$, $p < 10^{-5}$.

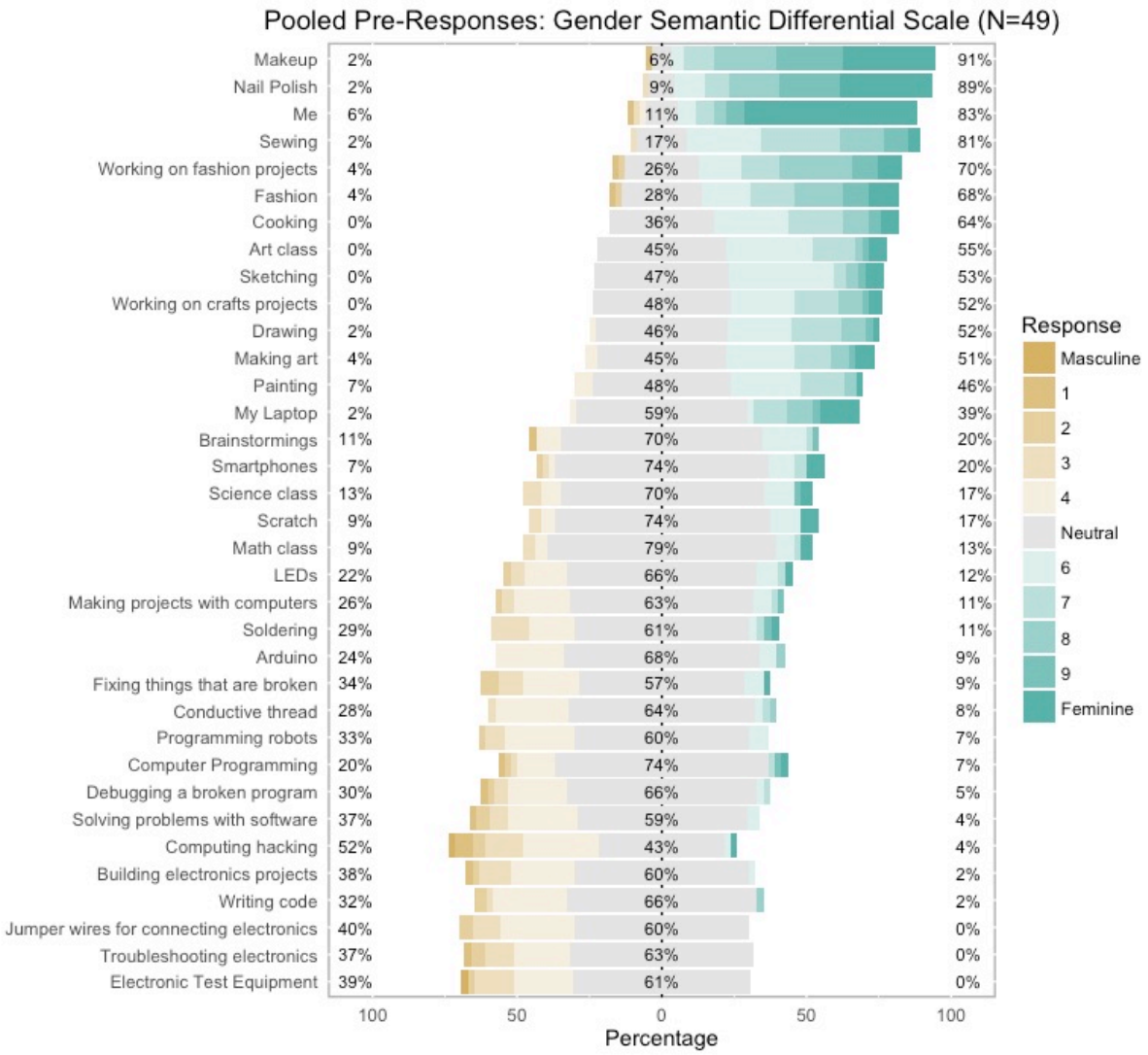

FIGURE 11: POOLED PRE-WORKSHOP RESPONSES (N=49) TO THE GENDER SEMANTIC DIFFERENTIAL SCALE

INFERENTIAL ANALYSIS OF GENDER SEMANTIC DIFFERENTIAL SCALE

When controlling for pre-workshop scores, girls in the WIRE group rated Programming and Items Encountered in the Workshop as more feminine when compared to the control group. To determine these effects, I performed two multiple regression analyses to detect changes on each underlying factor. The first analysis was equivalent to a one-way ANCOVA. The independent variable, workshop, involved three levels: WIRE, SEW, or Control. The dependent variable was the mean of all the post-workshop questions in the principal component of interest. The covariate was the mean of the pre-workshop questions from the same principal component. The second analysis included the interaction between workshop and pre-workshop mean. The covariates were centered in all analyses.

The results of each analysis are presented in a regression table. The results of the ANCOVA are reported in the first column labeled ANCOVA, and the results of the second analysis are reported in the second column labeled GLM (for Generalized Linear Model). Because the covariates were centered, the coefficient of the Intercept is the mean post-workshop score for the control group. The mean post-workshop score for the SEW group can be found by adding the SEW coefficient to the value of the Intercept. The same procedure can be used to find the mean post-workshop score for the WIRE group. A significant interaction means that the assumptions of the ANCOVA were violated, and in those cases I will attempt to provide an interpretation of the interaction.

FACTOR 1: ELECTRONICS VS. ARTS AND CRAFTS

No difference was detected for either workshop group on post-workshop scores when compared to the control group.

FACTOR 2: PROGRAMMING

There was a significant positive shift on the mean post-workshop measure for the participants in the WIRE group when compared to the control group ($p < 0.03$). Because masculine is coded 0 and feminine is coded 10, this means that the girls' gender stereotypes towards programming became more feminine in the WIRE group. No effect was found for the SEW group.

	ANCOVA	GLM
Intercept	4.40***	4.39***
	(0.10)	(0.10)
Pre(Centered)	0.48***	0.45***
	(0.08)	(0.08)
WIRE	0.47*	0.37
	(0.20)	(0.21)
SEW	0.27	0.22
	(0.20)	(0.21)
Pre(Centered)*WIRE		0.77
		(0.54)
Pre(Centered)*SEW		0.37
		(0.41)
R^2	0.53	0.56
Adj. R^2	0.50	0.50
Num. obs.	47	47
RMSE	0.52	0.52

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

TABLE 11: EXPLICIT GENDER STEREOTYPES RELATED TO PROGRAMMING

FACTOR 3: MAKEUP, FASHION, SMARTPHONES, LEDS

No difference was detected for either workshop group on post-workshop scores when compared to the control group.

FACTOR 4: ITEMS IN THE WORKSHOP

There was a trending positive shift on the mean post-workshop measure for the participants in the WIRE group when compared to the control group ($p < 0.09$). Because masculine is coded 0 and feminine is coded 10, this means that the girls' gender stereotypes towards programming became more feminine in the WIRE group. No effect was found for the SEW group. In other words, when compared to the control group, the girls in the WIRE group perceived items in the workshop ("Scratch", "My Laptop", "LEDs", "Conductive thread", and "Soldering") as more feminine after the workshop when controlling for pre-scores.

	ANCOVA	GLM
Intercept	2.00*	1.24
	(0.85)	(0.93)
Pre(Centered)	0.57**	0.72***
	(0.17)	(0.18)
WIRE	0.54·	5.45
	(0.31)	(3.46)
SEW	0.14	3.79
	(0.32)	(2.68)
Pre(Centered)*WIRE		−0.96
		(0.68)
Pre(Centered)*SEW		−0.67
		(0.49)
R^2	0.28	0.34
Adj. R^2	0.23	0.26
Num. obs.	47	47
RMSE	0.80	0.78

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

TABLE 12: EXPLICIT GENDER STEREOTYPES RELATED TO ITEMS IN THE WORKSHOP

FACTOR 5: ARTS AND SCIENCES

No difference was detected for either workshop group on post-workshop scores when compared to the control group.

DESCRIPTIVE ANALYSIS OF PRE-SCORES: IDENTITY SEMANTIC DIFFERENTIAL SCALE

The Identity Semantic Differential Scale is a 36-question survey that measures the participants' personal identification with a set of attitude objects. Each item is rated on a scale from "Not my thing" (0) to "My kind of thing or could be my kind of thing" (10). For example, one question asks participants to rate "Making projects with computers" as either "Not my thing" (coded 0) or "My kind of thing or could be my kind of thing" (coded 10). The further the slider is pushed towards 10, the more the participant identifies with the item. I created the Identity Semantic Differential Scale to complement to the Identity GNAT. While the Identity GNAT is intended to measure implicit attitudes towards computing and arts, the Identity Semantic Differential Scale is intended to measure the participants' explicit attitudes on a similar set of items.

I initially intended the Identity Semantic Differential Scale to measure two latent factors: explicit identification with computing and explicit identification with arts. However, a chi-square goodness of fit rejected the hypothesis that two principal components were sufficient to fit the data. The same test failed to reject the hypothesis that three principal components were sufficient. In other words, three principal components were necessary to capture the variability in the responses. Initial eigenvalues indicated that the first three factors explained 28%, 17%, and 12% of the variance respectively.

Factor Number	Description	Number of Questions that Load onto Factor	Variance Explained	Alpha
1	Computing	16	0.28	0.95
2	Arts and Making	11	0.17	0.91
3	Makeup, fashion, cooking, sewing	7	0.12	0.86

TABLE 13: LATENT FACTORS IN THE IDENTITY SLIDERS SURVEY

A plot of the pooled pre-workshop responses to the Identity Semantic Differential Scale can be found in Figure 12. One interesting thing to note is that the girls' rated "Makeup", "Nail Polish", and "Me" as the most feminine items in the Gender Semantic Differential Scale. However, in this scale "Makeup" and "Nail Polish" are the two items that the girls least identify with.

In order to compare the girls' explicit attitudes to their implicit attitudes, I matched items from the Identity Semantic Differential Scale to items presented in the Identity GNAT and created two categories: Computing and Arts. A paired t-test showed that the girls were more likely to rate the arts questions as more "My Kind of Thing" (mean=7.06, sd=1.80) than the computing questions (mean=5.97, sd=1.99); $t(21)=-2.53$, $p < 0.02$.

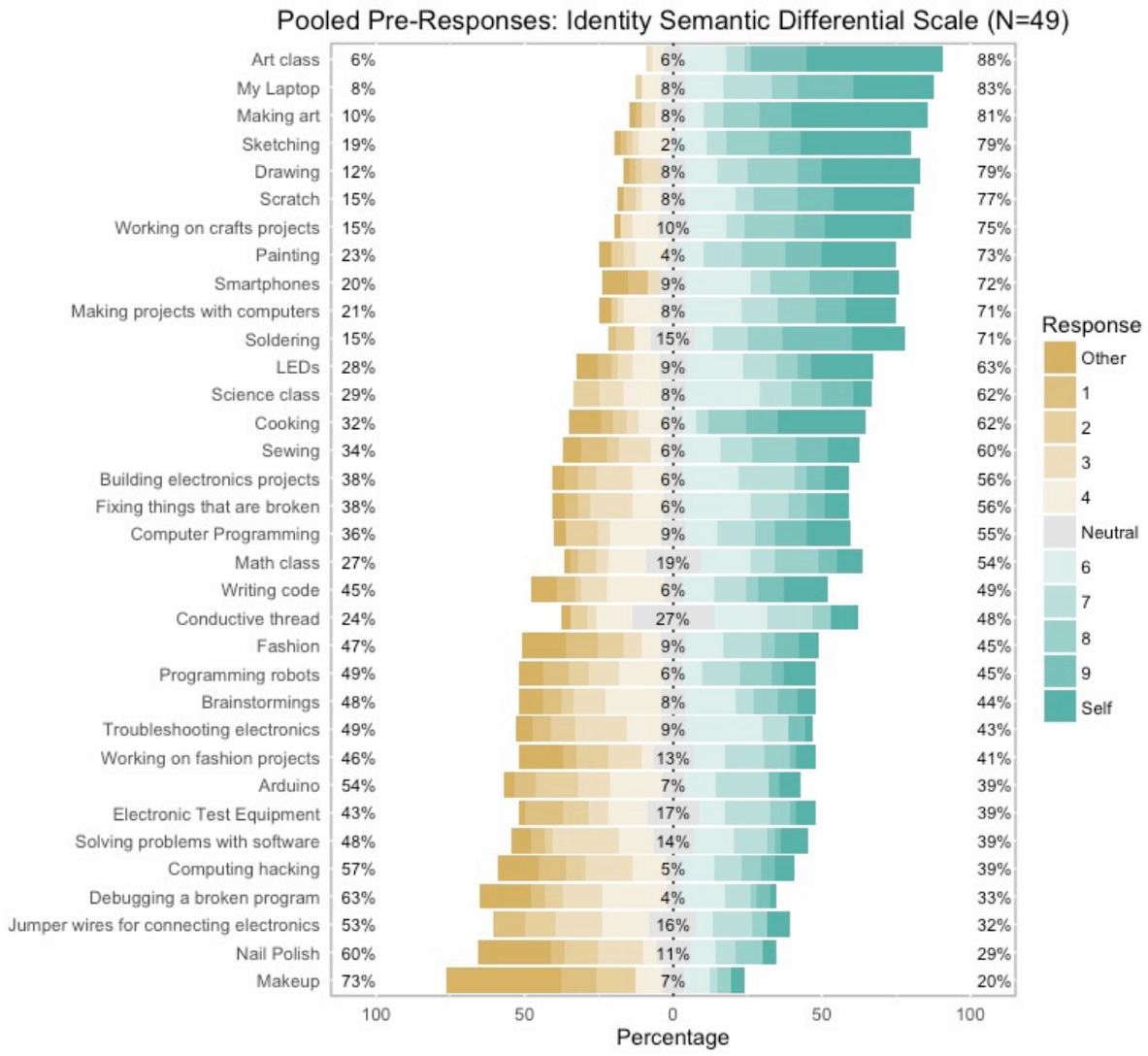

FIGURE 12: POOLED PRE-WORKSHOP RESPONSES (N=49) TO THE IDENTITY SEMANTIC DIFFERENTIAL SCALE

INFERENTIAL ANALYSIS OF IDENTITY SEMANTIC DIFFERENTIAL SCALE

When controlling for pre-workshop scores, girls in the SEW group identified less with Arts and Making than the girls in the Control group. To determine these effects, I performed the same set of analyses as in the Gender Semantic Differential Scale: a one-way ANCOVA and a GLM involving the interaction between workshop and pre-workshop measures. When significant, the results of each analysis are presented in a regression table below.

FACTOR 1: COMPUTING

In the ANCOVA, no difference was detected for either workshop group on post-workshop scores when compared to the control group. However, a significant negative interaction was detected for the WIRE group.

	ANCOVA	GLM
Intercept	5.69^{***}	5.77^{***}
	(0.22)	(0.22)
Pre(Centered)	1.51^{***}	1.80^{***}
	(0.18)	(0.22)
WIRE	-0.11	-0.03
	(0.44)	(0.42)
SEW	-0.27	-0.37
	(0.47)	(0.52)
Pre(Centered)*WIRE		-1.02^{*}
		(0.41)
Pre(Centered)*SEW		-0.26
		(0.53)
R^2	0.63	0.68
Adj. R^2	0.60	0.64
Num. obs.	48	48
RMSE	1.17	1.12

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

TABLE 14: EXPLICIT PERSONAL IDENTIFICATION WITH COMPUTING

FACTOR 2: ARTS AND MAKING

There was a significant negative shift on the mean post-workshop measure for the participants in the SEW group when compared to the control group ($p < 0.05$). Because other is coded 0 and self is coded 10, this means that the girls' personal identification with arts and making decreased in the SEW group. No effect was found for the WIRE group. A deeper look into the factor found that there was change on "LEDs" (SEW group decreased), "Conductive Thread" (SEW group decreased), and "Art Class" (SEW group decreased).

	ANCOVA	GLM
Intercept	7.07^{***}	7.10^{***}
	(0.14)	(0.14)
Pre(Centered)	1.40^{***}	1.54^{***}
	(0.11)	(0.15)
WIRE	0.07	0.12
	(0.28)	(0.28)
SEW	-0.61^{*}	-0.67^{*}
	(0.29)	(0.30)
Pre(Centered)*WIRE		$-0.43^{\cdot}$
		(0.25)
Pre(Centered)*SEW		-0.03
		(0.38)
R^2	0.78	0.80
Adj. R^2	0.77	0.77
Num. obs.	48	48
RMSE	0.76	0.75

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

TABLE 15: EXPLICIT PERSONAL IDENTIFICATION WITH ARTS AND MAKING

FACTOR 3: MAKEUP, FASHION, COOKING, SEWING

No difference was detected for either workshop group on post-workshop scores when compared to the control group.

DESCRIPTIVE ANALYSIS OF THE ATTITUDES TOWARDS COMPUTING INSTRUMENT (ATCI)

The Attitudes Towards Computing Instrument (ATCI) is an eight-question survey that measures a single latent factor: attitude towards computers (Shaft, Sharfman, & Wu, 2004). Those taking the survey move a slider between two adjectives that refer to computers. For example, one question asks participants to rate computers as either harmful (coded 1) or helpful (coded 7). The further the slider is pushed towards 7, the more helpful the participant sees computers.

Although the creators of the ATCI claim that the survey measures a single latent factor, the survey was validated with college students. Because the participants in my study were middle-school students, I felt it necessary to check the number of underlying factors using principal components analysis. Unfortunately, a chi-square goodness of fit rejected the hypothesis that a single principal component was sufficient to fit the data. The same test failed to reject the hypothesis that three principal components were sufficient. In fact, a chi-square goodness of fit test rejected the hypothesis that anything below four factors was sufficient to fit the data. In other words, at least five factors were necessary to capture the variability in the responses. The large difference between the number of factors the ATCI was supposed to measure (one) and the number it measured in this case (at least five) is concerning. Initial eigenvalues indicated that the first five factors explained 27%, 21%, 15%, 14%, and 13% of the variance respectively.

Factor Number	Description	Number of Questions that Load onto Factor	Variance Explained	Alpha
1	Worthless vs. Worthwhile	3	0.27	0.72
2	Decrease Productivity vs. Increase Productivity	1	0.15	0.85
3	Threatening vs. Non-Threatening	1	0.14	0.86
4	Hard vs. Easy to Use	2	0.21	0.7
5	Restrain vs. Enhance Creativity	1	0.13	0.83

TABLE 16: LATENT FACTORS IN THE ATTITUDES TOWARDS COMPUTING INSTRUMENT

A plot of the pooled pre-workshop responses to the ATCI can be found in Figure 13. The girls' attitudes towards computing are very high.

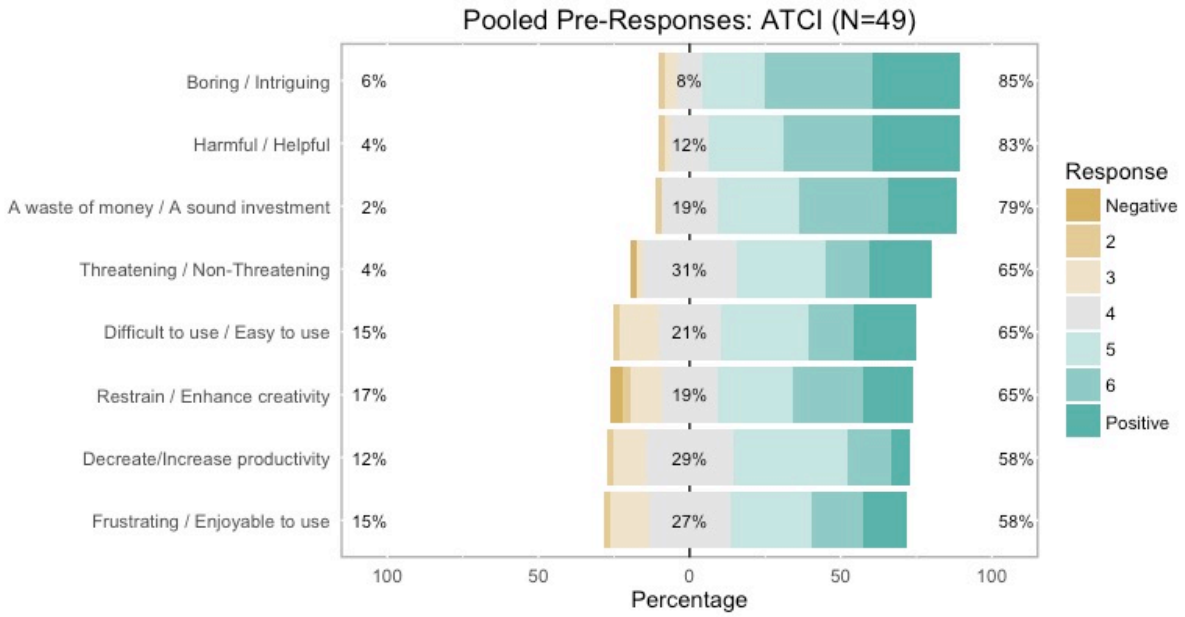

FIGURE 13: POOLED PRE-WORKSHOP RESPONSES (N=49) TO THE ATTITUDES TOWARDS COMPUTING INSTRUMENT (ATCI)

INFERENTIAL ANALYSIS OF THE ATTITUDES TOWARDS COMPUTING INSTRUMENT

I performed a one-way ANCOVA and a GLM involving the interaction between workshop and pre-workshop measures. However, I found no significant differences from pre-workshop to post-workshop in the WIRE or SEW groups on any group of questions. This is most likely due to the fact that the girls hit the ceiling on this measure in the pre-workshop instrument.

DESCRIPTIVE ANALYSIS OF THE GENERAL IDENTITY INSTRUMENT

The General Identity instrument was adapted from the Access, Interest, and Experience survey (Barron et al., 2010; Tellez, 2013). It is composed of 16 7-item likert-scale questions that are designed to measure the participants' personal identification with computing, their interest in learning more about computing, and whether it is important to their friends, family, and teachers if they know about computers. For example, one question asks participants to rate if someone like them could be a computer scientist from strongly agree (coded 7) or strongly disagree (coded 1).

A chi-square goodness failed to reject the hypothesis that three factors were sufficient to fit the data ($p < 0.84$). In other words, three factors were enough to capture the variability in the responses. The three factors found by PCA are summarized in Table 17 below. Initial eigenvalues indicated that the first three factors explained 38%, 17%, and 12% of the variance respectively.

Factor Number	Description	Number of Questions that Load onto Factor	Variance Explained	Alpha
1	Personal and group identification with computing	11	0.38	0.91
2	Importance of computing to me and others (not teachers)	5	0.17	0.47
3	Enjoyment of computing	4	0.12	0.79

TABLE 17: LATENT FACTORS IN THE GENERAL IDENTITY INSTRUMENT

A plot of the pooled pre-workshop responses to the General Identity instrument can be found in Figure 14.

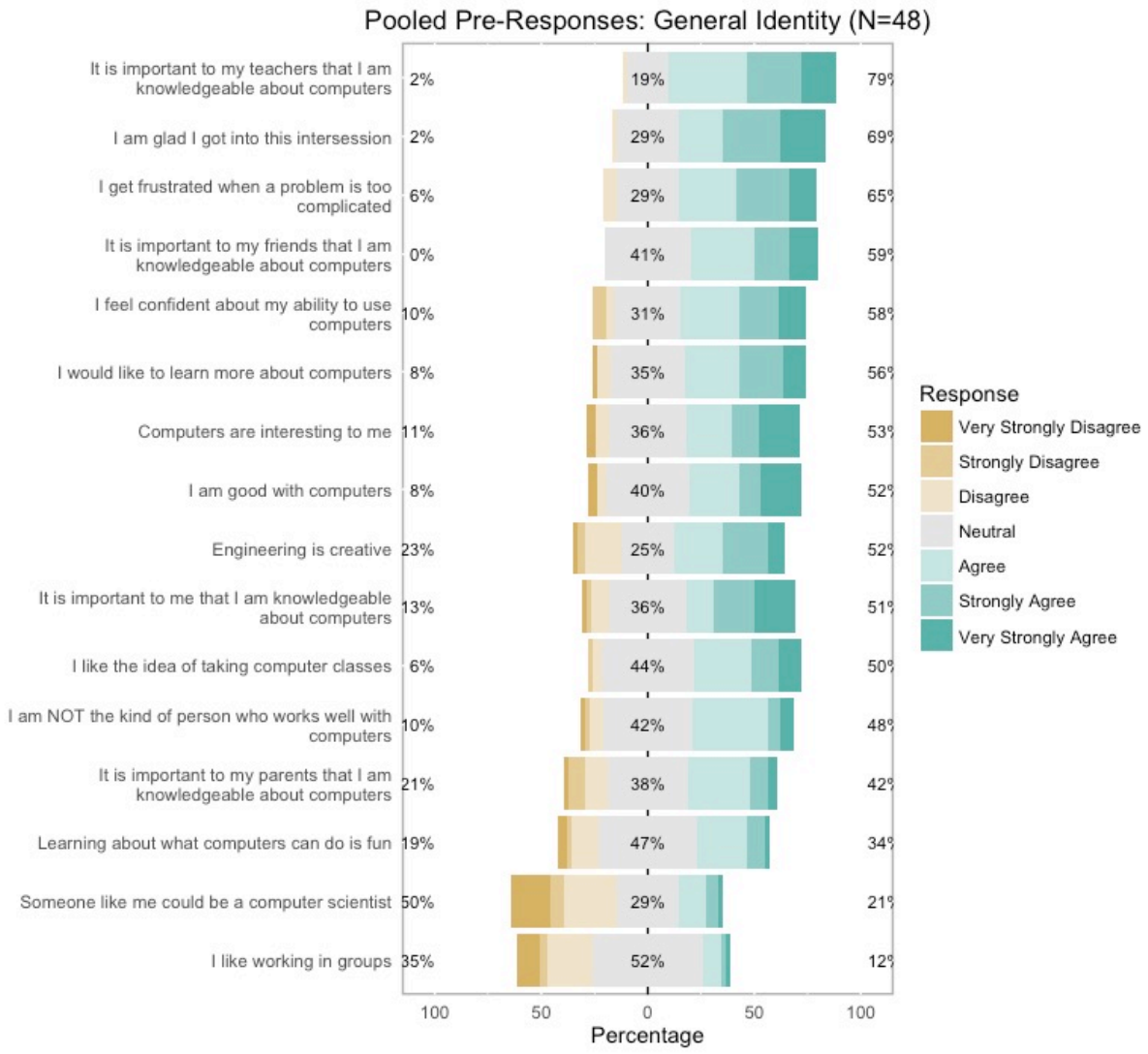

FIGURE 14: POOLED PRE-WORKSHOP RESPONSES (N=49) TO THE GENERAL IDENTITY INSTRUMENT

INFERENTIAL ANALYSIS OF THE GENERAL IDENTITY INSTRUMENT

When controlling for pre-workshop scores, girls in the SEW group scored significantly higher on Personal and Group Identification with Computing and trended higher on Enjoyment of computing when compared to the Control group. To determine these effects, I performed a one-way ANCOVA and a GLM involving the interaction between workshop and pre-workshop measures. When significant, the results of each analysis are presented in a regression table below.

FACTOR 1: PERSONAL AND GROUP IDENTIFICATION WITH COMPUTING

There was a significant positive shift on the mean post-workshop measure for the participants in the SEW group when compared to the control group ($p < 0.04$). This means that, relative to the control group, the girls' personal and group identification with computing increased in the SEW group. Although a significant negative interaction was found between the WIRE group and the pre-scores, the significant increase for SEW remained.

	ANCOVA	GLM
Intercept	4.97^{***}	4.98^{***}
	(0.08)	(0.08)
Pre(Centered)	0.84^{***}	0.94^{***}
	(0.06)	(0.08)
WIRE	0.02	0.08
	(0.15)	(0.15)
SEW	0.35^{*}	0.34^{*}
	(0.16)	(0.15)
Pre(Centered)*WIRE		-0.30^{*}
		(0.14)
Pre(Centered)*SEW		-0.13
		(0.17)
R^2	0.82	0.84
Adj. R^2	0.81	0.82
Num. obs.	48	48
RMSE	0.41	0.40

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

TABLE 18: EXPLICIT PERSONAL AND GROUP IDENTIFICATION WITH COMPUTING

FACTOR 2: IMPORTANCE OF COMPUTING TO ME AND OTHERS

No difference was detected for either workshop group on post-workshop scores when compared to the control group.

FACTOR 3: ENJOYMENT OF COMPUTING

There was a nearly significant increase in post-scores on this factor for the SEW group when compared to the control group ($p < 0.08$). Relative to the control group, the girls in the SEW group had higher post-workshop scores when controlling for pre-scores. There were no significant interactions to report.

	ANCOVA	GLM
Intercept	1.32^{**}	1.57^{**}
	(0.46)	(0.52)
Pre(Centered)	0.63^{***}	0.57^{***}
	(0.11)	(0.12)
WIRE	0.24	-1.38
	(0.26)	(1.44)
SEW	$0.49^{\cdot}$	-0.07
	(0.27)	(1.53)
Pre(Centered)*WIRE		0.36
		(0.32)
Pre(Centered)*SEW		0.13
		(0.36)
R^2	0.48	0.50
Adj. R^2	0.45	0.44
Num. obs.	48	48
RMSE	0.70	0.71

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

TABLE 19: EXPLICIT PERSONAL ENJOYMENT OF COMPUTING

DESCRIPTIVE ANALYSIS OF THE FUTURE CAREER AND EDUCATIONAL GOALS INSTRUMENT

The Future Career and Educational Goals survey was adapted from the Access, Interest, and Experience survey (Barron et al., 2010; Tellez, 2013). It is composed of 26 questions that ask the participant to rate their future career goals (e.g., becoming a computer programmer) and their future educational goals (e.g., learning more about hardware) on a 7-item Likert scale. The possible answers range from "Definitely no" (1) to "Definitely yes" (7).

A chi-square goodness failed to reject the hypothesis that two factors were sufficient to fit the data ($p < 1$). In other words, two factors were enough to capture the variability in the responses. Initial eigenvalues indicated that the first two factors explained 40% and 16% of the variance respectively. The two factors found by PCA are summarized in Table 20 below.

Factor Number	Description	Number of Questions that Load onto Factor	Variance Explained	Alpha
1	Interest in Engineering	19	0.4	0.94
2	Interest in Anything Else	10	0.16	0.8

TABLE 20: LATENT FACTORS IN THE FUTURE GOALS SURVEY

A plot of the pooled pre-workshop responses to the Future Careers and Educational Goals instrument can be found in Figure 15.

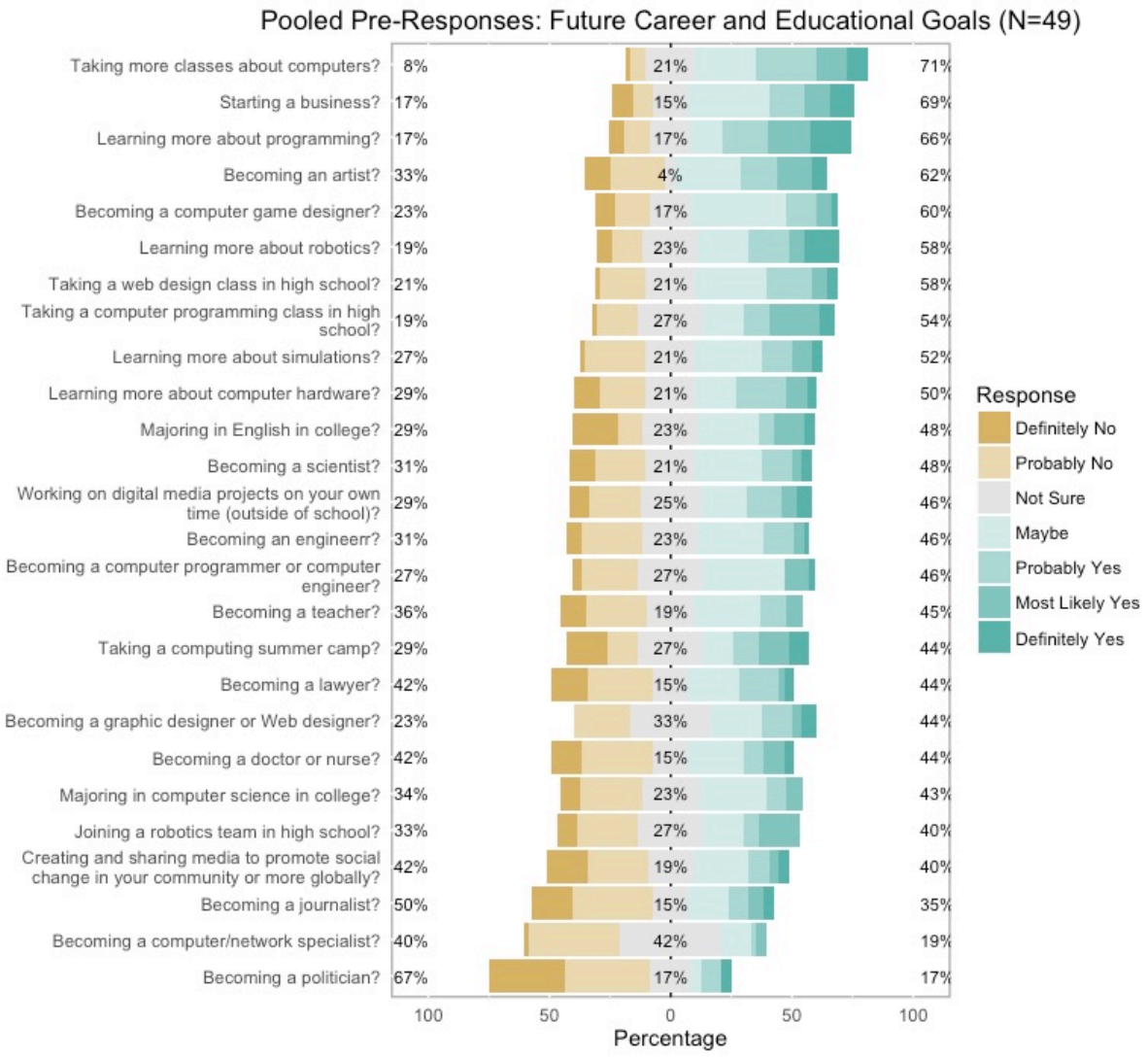

FIGURE 15: POOLED PRE-WORKSHOP RESPONSES (N=49) TO THE FUTURE CAREERS AND EDUCATIONAL GOALS INSTRUMENT

INFERENTIAL ANALYSIS OF THE FUTURE CAREER AND EDUCATIONAL GOALS INSTRUMENT

I performed a one-way ANCOVA and a GLM involving the interaction between workshop and pre-workshop measures. However, I found no significant differences from pre-workshop to post-workshop in the WIRE or SEW groups on any group of questions.

DISCUSSION

IMPLICIT GENDER STEREOTYPES ALIGN WITH EXPLICIT GENDER STEREOTYPES

When looking at the pooled pre-workshop scores for the entire sample of participants (N=49), data from the Gender GNAT showed that the girls automatically associated computing with male and arts with female. Moreover, data from the Gender Semantic Difference Scale shows that the girls' explicit, conscious stereotypes towards computing and arts were also stereotyped in the same ways. On both implicit and explicit measures, at the start of the workshop the girls viewed computing as a masculine activity and arts as a feminine activity.

IMPLICIT IDENTITY CONTRADICTS EXPLICIT IDENTITY

When looking at the pooled pre-workshop scores for the entire sample of participants (N=49), data from the Identity GNAT showed that the girls were no more likely to automatically identify with arts than they were with computing. There were also equally likely to associate computing with self as they were with other. However, on the Identity Semantic Differential Scale, the girls were significantly more likely to associate arts with self than computing with self. Differences in explicit and implicit measures of similar attitudes are a well-documented phenomenon (Hofmann, Gawronski, Gschwendner, Le, & Schmitt, 2005), with one of the potential reasons for the mismatch being social desirability bias: the tendency for people to present a favorable image of themselves on self-report surveys (Mortel & F, 2008). If social desirability bias is indeed the cause of the mismatch, this would mean that the participants place higher value on being seen as artistic than being seen as a computer person.

TOOL DESIGN IMPACTS GENDER PERCEPTION AND THE BI-DIMENSIONALITY OF GENDER AND PERSONAL IDENTITY

When comparing post-workshop d-prime values between experimental groups, data from the Gender GNAT indicated that girls in the WIRE group were more likely to associate male and computing and male and arts. The causal interpretation is that participation in the WIRE group—using the more traditional Arduino Leonardo, breadboards, soldering irons, and wire—led to an increase in the girls' implicit association between male and computing as well as male and arts. The theoretical explanation for this finding is that the gender valence of the tools remained constant (masculine) for the duration of the workshop, and that prolonged exposure to these tools shifted the girls' automatic associations around workshop activities to be more stereotyped. The flip side of this argument is that exposure to the tools used in the SEW group—the Adafruit Flora, the conductive thread, fabric—did not shift the girls' automatic associations.

Furthermore, data from the Identity GNAT indicated that girls in the WIRE group were significantly more likely to associate computing with other than the girls in the SEW group. Recall that on the Gender GNAT, the girls in the WIRE group more strongly associated computing with male on the post-workshop measure. The theoretical link between these two findings is that prolonged exposure to the

tools in the WIRE group shifted the girls' automatic associations between male and computing, which also impacted their automatic associations between other and computing.

It is important to note that no differences were found on the girls' automatic associations between self and computing. That is, even though using the tools in the WIRE group increased the girls' implicit associations of computing with male and computing with other, this did not come at the expense of their automatic association of computing with female or computing with self.

One way of making sense of these findings—that girls can see computing as more masculine without seeing it as less feminine, or that they can become more likely to associate computing with others without becoming less likely to associate computing with self—is to adopt a bi-dimensional view of gender and self-concept (Constantinople, 1973). Instead of thinking of computing as being either masculine or feminine, with more masculine automatically meaning less feminine, a bi-dimensional view of gender allows for the masculinity and femininity of computing to vary independently.

HIGHLY AMBIGUOUS RESULTS ON THE GENDER SEMANTIC DIFFERENTIAL SCALE

A quick glance at Figure 11 shows that the girls had trouble rating most of the questions on the Gender Semantic Differential Scale. On nearly all items the most common rating is 5, or gender neutral. Because the semantic differential scale forced participants to treat gender as bipolar, it is impossible to know if these items are rated neutral because the girls have no strong gender stereotypes towards those items (ambivalent) or if they are rated neutral because the girls see those items as both masculine and feminine (androgynous). A bi-dimensional semantic differential scale would not have suffered from this problem. In future studies participants will be asked to rate each item along two different dimensions: masculine (from not masculine at all to extremely masculine) and feminine (from not feminine at all to extremely feminine).

INVERSION OF EXPECTED RESULTS LINKING GENDER STEREOTYPES AND TOOL DESIGN ON EXPLICIT MEASURES

When comparing post-workshop scores on the Gender Semantic Differential Scale between experimental groups, girls in the WIRE group rated Programming and Items Encountered in the Workshop as more feminine when compared to the control group. This is a surprising finding for two reasons. First, the girls in the WIRE group were more likely to automatically associate Computing and Arts as more masculine on the Gender GNAT. This means that the girls' implicit stereotypes moved in one direction while their explicit stereotypes moved in the opposite direction. Second, the tools in the WIRE group were theorized to push the girls' towards more stereotyped views of computing (i.e., computing as masculine), while the tools in the SEW group were theorized to make the girls' more likely to see computing as feminine. This finding flies in the face of the theorized relationship.

CHANGES IN IDENTIFICATION FOR GIRLS IN THE SEW GROUP

When comparing post-workshop scores on the Identity Semantic Differential Scale between experimental groups, girls in the SEW group identified less with Arts and Making than the girls in the

Control group. A deeper look into the factor found changes on three items: “LEDs” (SEW group decreased), “Conductive Thread” (SEW group decreased), and “Art Class” (SEW group decreased).

However, the girls in the SEW group scored significantly higher on Personal and Group Identification with Computing and trended higher on Enjoyment of computing when compared to the Control group. A deeper look into these two factors found that both of these effects were being driven by a single question that loaded onto both factors: “I am good with computers.”

LIMITATIONS

Interpreting the inferential results from this study should be done with care. Both experimental groups had a low sample size (N=10 in both), which decreases the reliability of the statistical results. Furthermore, due to the length of the full survey, it is likely that the participants suffered from test fatigue. Indeed, test fatigue seemed to effect a number of the girls during the GNAT portion of the survey, resulting in a large number of errors that were thrown out prior to analysis. Fortunately, the descriptive results do not suffer as extremely from these problems. Pooling the entire sample together resulted in a respectable sample size that leads to increased reliability of the results (N=49).

CONCLUSION

This study was designed to learn more about how the design of different hardware construction kits could impact girls’ stereotypes and self-concept related to computing and arts. The results were inconclusive. While there was some evidence that using the tools in the WIRE workshop shifted the girls’ implicit stereotypes towards computing and led them to associate computing more with other people, there was no comparable effect for the girls in the SEW workshop. Furthermore, the shift in gender stereotypes seemed unrelated to the change in self-concept. Despite the shift in implicit gender stereotypes regarding computing, the WIRE group did not shift in any measures of identity related to computing. And despite not shifting in any measures of gender stereotype, the SEW group did shift in its identification with computing.

What is one to make of all this? The surest conclusion is that the effects of the different tool design on the girls’ attitudes were slight. Whether the girls used the sewable electronics or the more traditional kits with wires, it did not seem to matter much. And regardless of condition, the girls were able to successfully design and build interactive projects over the course of the workshop.

Of course, these toolkits may affect interest, motivation, and other psychological constructs through less direct mechanisms. Perhaps, because of the way they are marketed, these kits will simply provide more girls with opportunities to learn about programming and engineering at a young age. Schools and libraries may be more likely to buy them, adults may be more likely to give them as presents, or women may be more likely to buy them for themselves. Or, perhaps in a mixed-gender classroom where boys tend to monopolize the computing kits, girls will feel entitled to claim these kits for themselves.

The results from this study do not contradict any of these claims. What this study calls into question is the claim that altering the gender valence of engineering kits can shift girls’ gender stereotypes or identification with computing. The results from this study become concerning when

considering the increasing number of engineering kits that attempt to recast engineering as a girls' domain. Although the intention is noble, this study provides evidence that it may be more difficult to change the minds of young girls than these companies realize. Closing the gender gap should be one of our highest educational priorities. But we should not let ourselves be so blinded by our desire to solve this problem that we do not critically evaluate the claims of those who are attempting to sell us a solution.

ACKNOWLEDGEMENTS

I would like to thank the Lopatin family for their generous support of this project.

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