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

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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. We found that at the start of the study the girls held largely stereotypical attitudes, and that these attitudes became less stereotyped for the girls in the experimental groups. Furthermore, we found little difference between the two experimental groups, casting doubt on prior claims as to the effectiveness of gendered construction kits on girls' interest in and attitudes towards computing.

OBJECTIVES

This paper aims to answer the following research questions.

1. What are middle-school girls' pre-existing attitudes towards computer science (CS) and arts/crafts?
2. How do these attitudes change as a result of working with functionally-similar, differently-themed toolkits?

Note that this paper is the first to use implicit attitudes measures (the Go/No-Go Association Test) alongside more traditional explicit measures, giving a more complete view of these attitudes. Furthermore, this is the first study to use an experimental design to explore how the design features of differently-gendered construction kits affect girls' attitudes towards computing.

THEORETICAL FRAMEWORK

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 we 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).

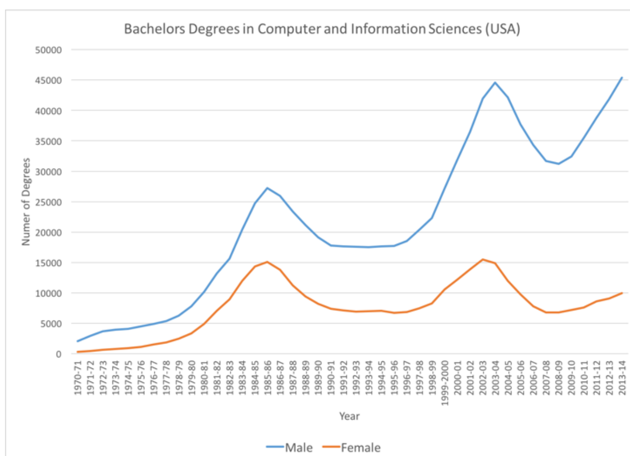

FIGURE 1: DEGREES IN COMPUTING FROM 1970 TO 2014 (USA)

CHANGING THE TOOLS, 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. One of the theories as to how this may be accomplished is by changing the design features and affordances of the tools students use. This phenomenon has been studied for decades in computing. 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. 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. 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). There is a growing body of literature 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.

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.

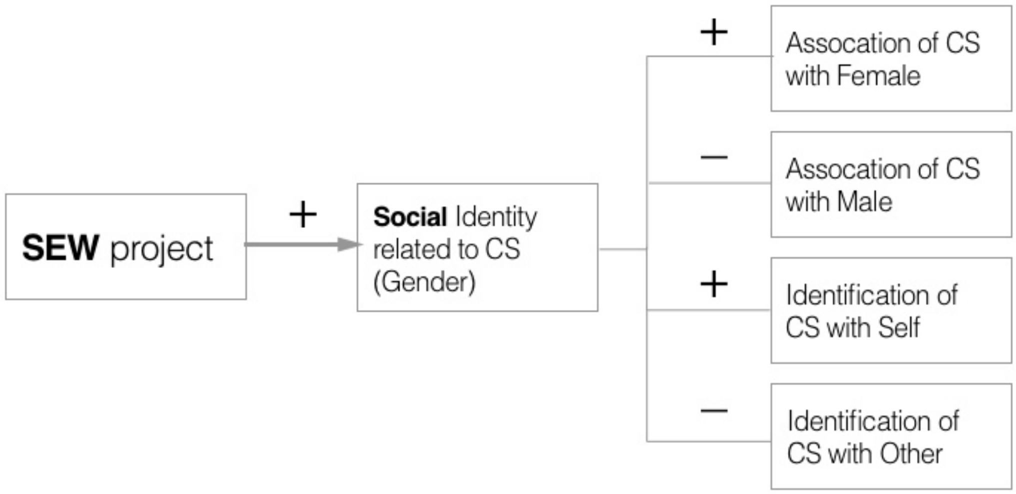

FIGURE 2: THEORIZED LINK BETWEEN SOCIAL (GENDER) IDENTITY AND USING STEREOTYPICALLY FEMALE TOOLS (ADAFRUIT FLORA) AND WORKING ON STEREOTYPICALLY FEMALE PROJECTS (FASHION). BEING IN THE SEW GROUP IS EXPECTED TO INCREASE SOCIAL (GENDER) IDENTITY RELATED TO CS.

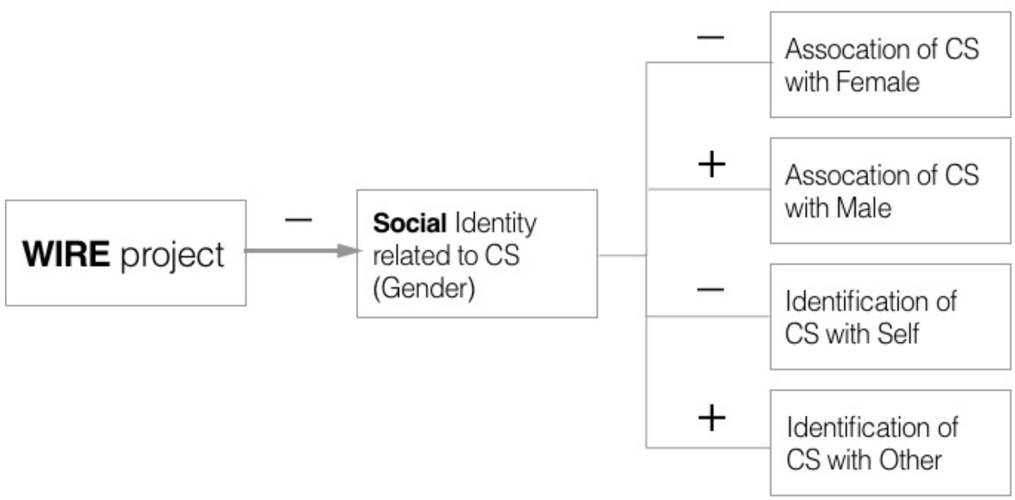

FIGURE 3: THEORIZED LINK BETWEEN SOCIAL (GENDER) IDENTITY AND USING STEREOTYPICALLY MALE TOOLS (ARDUINO LEONARDO). BEING IN THE WIRE GROUP IS THEORIZED TO LOWER SOCIAL (GENDER) IDENTITY RELATED TO CS.

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).

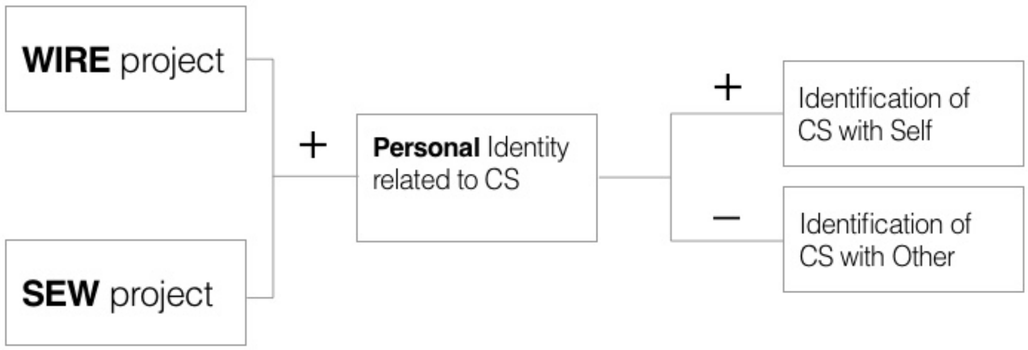

FIGURE 4: THEORIZED LINK BETWEEN PERSONAL IDENTITY AND THE TWO WORKSHOPS. IN BOTH CASES, PERSONAL IDENTITY WITH CS IS EXPECTED TO INCREASE.

METHODS AND INSTRUMENTS

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 a week-long break from normal classes called intersession 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 (Figure 5) in a workshop called Electric Fashion. The second group—the Workshop Involving Regular Electronics (WIRE)—used a more traditional Arduino Leonardo (Figure 6) 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 full list of sensors and actuators provided for each group is reported in Table 1 below.

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. The instruments assessed identity, gender stereotypes, and general attitudes towards computers. The names of the instruments measuring identity were the Identity GNAT and the Identity Semantic Differential Scale, and the names of the instruments measuring gender stereotypes were the Gender GNAT and the Gender Semantic Differential Scale.

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

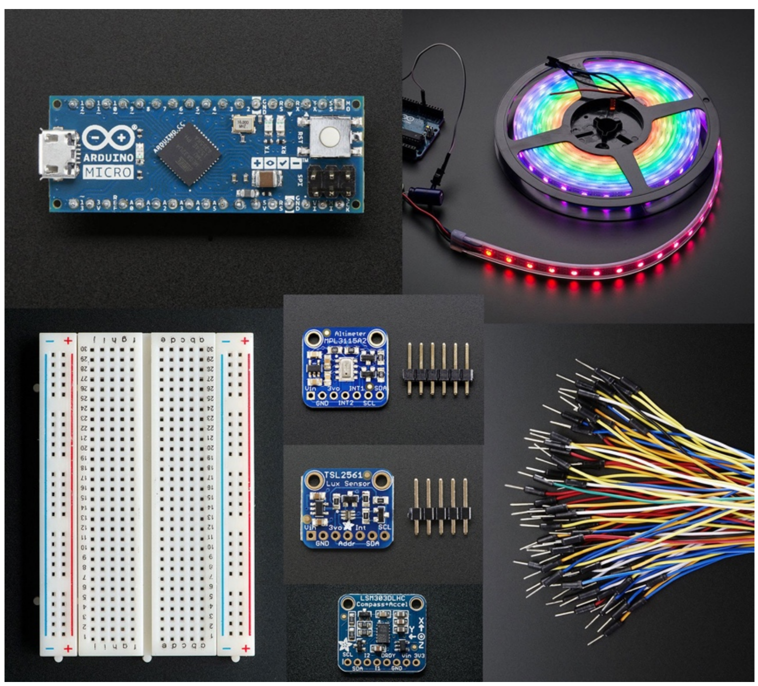

FIGURE 6: MATERIALS USED IN THE WIRE GROUP. CLOCKWISE FROM TOP-LEFT: ARDUINO LEONARDO, LED STRIP, WIRES, PRESSURE SENSOR, LIGHT SENSOR, ACCELEROMETER, AND BREADBOARD

	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

RESULTS

PRE-INTERVENTION, GIRLS HOLD STEREOTYPED VIEWS TOWARDS COMPUTING AND ARTS

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 7.

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.

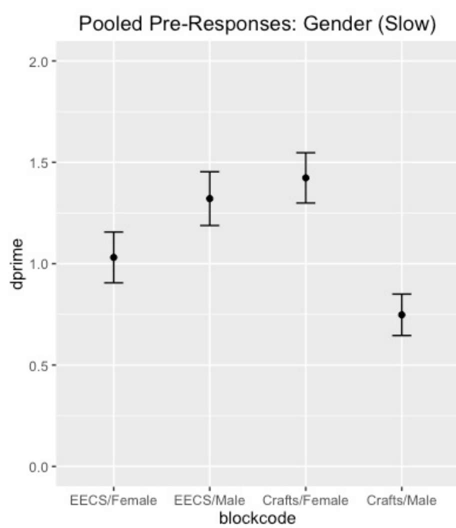

FIGURE 7: MEAN D-PRIME VALUES OF POOLED PRE-RESPONSES ON THE GENDER GNAT. ERROR BARS SHOW STANDARD ERROR

In order to compare the girls' explicit attitudes to their implicit attitudes, we matched items from the Gender Semantic Differential Scale (Figure 9) to items presented in the Gender GNAT and created two categories: Computing and Arts (Figure 8). 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); $t(31)=-6.434$, $p < 10^{-5}$.

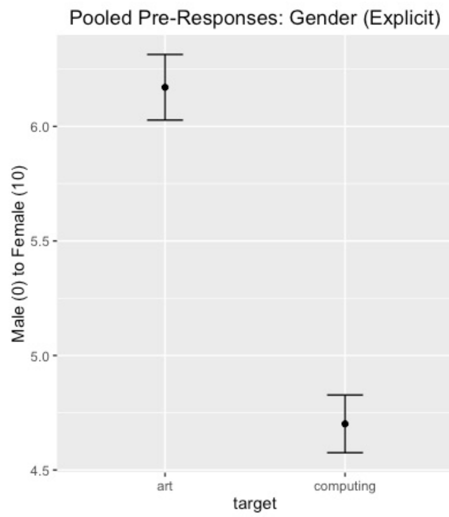

FIGURE 8: PARTICIPANTS VIEW ARTS AS MORE FEMALE AND COMPUTING AS MORE MALE

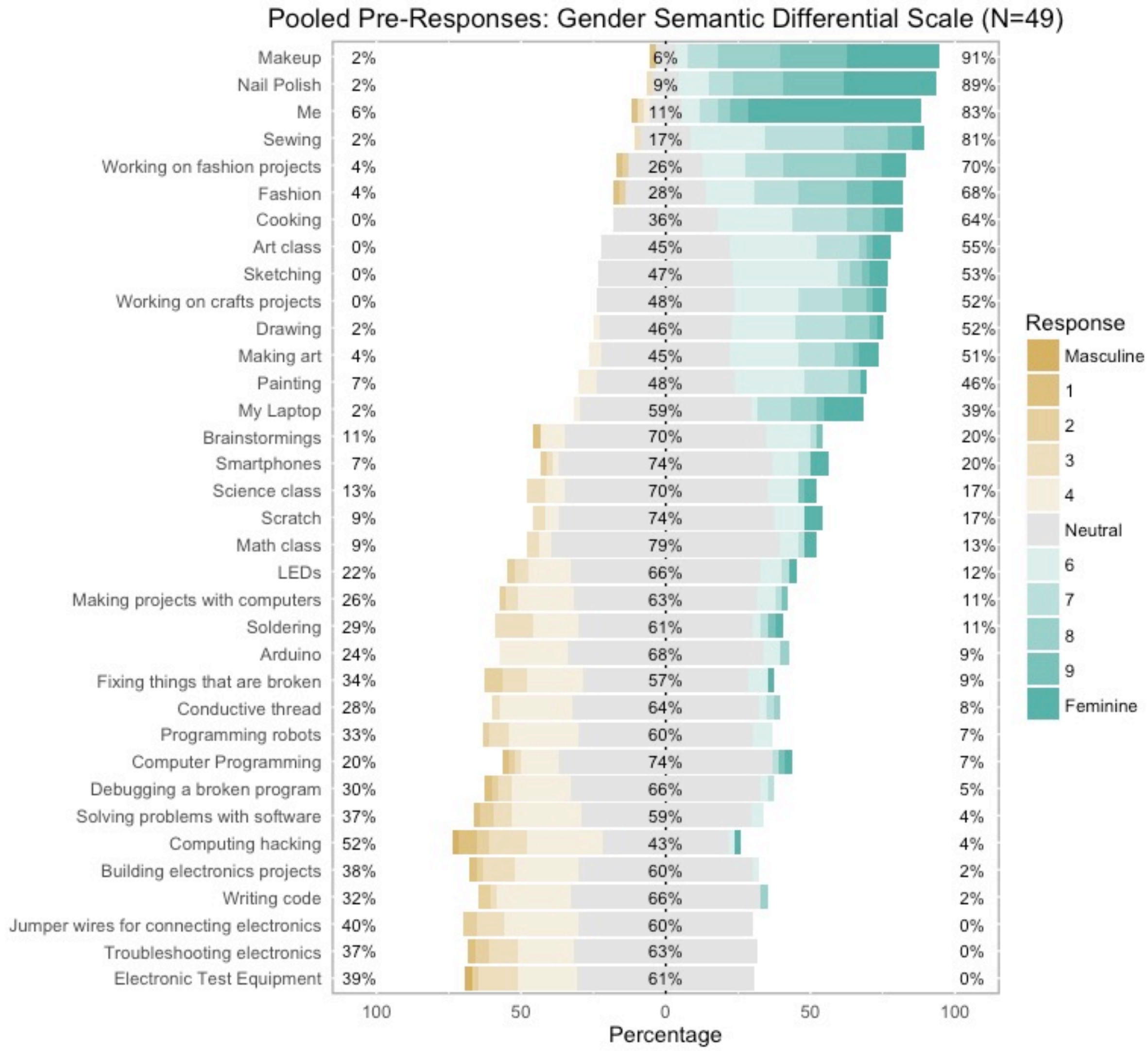

FIGURE 9: POOLED PRE-WORKSHOP RESPONSES (N=49) TO THE GENDER SEMANTIC DIFFERENTIAL SCALE

WORKSHOP PARTICIPATION SHIFTS ATTITUDES

Workshop participants' attitudes shifted in two distinct ways. First, participants in both workshops were more likely to associate computing with girls than participants in the control group. For instance, participants in both groups shifted in their perception of the "Arduino" ($p < 0.06$). Second, participants in the SEW group were more likely to associate some crafts activities with boys. For instance, girls in the SEW group reported that "Working on Fashion Projects" was more masculine after the workshop ($p < 0.06$). There were no notable shifts in implicit attitudes.

CONCLUSION (SCHOLARLY SIGNIFICANCE)

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 first contribution to the field is the use of the Go/No-Go Association Test to measure middle-school girls' implicit attitudes towards computing. To the authors' knowledge, this type of measure has never been used in this way before. Thus we are the first to learn that girls' implicit attitudes towards computing are stereotyped, and that their implicit attitudes match their explicit attitudes.

The second contribution to the field is the use of an experimental design, complete with a control group, to directly compare the effects of using different types of computational toolkits on attitudes. We are unaware of any other study that has used this type of design to look at how working with different types of physical computing toolkits can affect gender stereotypes.

While the results showed that participation in the workshop was enough to shift attitudes towards computing, the effects were found in both groups. 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. 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.

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