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# Kids, Robotics, and Gender: a pilot study

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# Kids, Robotics, and Gender: a pilot study

Thesis

submitted by

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*For my daughter,*[1] *that she will not feel gender defines who she can be.*

[1] hypothetical future

# Abstract

Children as young as first and second grade display both implicit and explicit awareness of stereotypes regarding gender and engineering [Steele, 2003]. The *Kids Invent With Imagination* (KIWI) Robotics kit combined with the *Creative Hybrid Environment for Robotic Programming* (CHERP) [Bers *et al.*, 2013] programming interface provides a developmentally appropriate medium to teach computer programming, robotics, and engineering in early-childhood classrooms. This paper explores the impact of collaborative curriculum on teaching robotics to first and second grade students, and the impacts of curricular robotics on reducing gender-based engineering stereotypes. Overall, the study demonstrates the potential to dramatically reduce, and in some cases remove, gender-based engineering stereotype awareness in children following a collaborative robotics unit in the classroom.

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# List of Acronyms

**AP** Advanced Placement
**CHERP** Creative Hybrid Environment for Robotic Programming
**CITI** Collaborative Institutional Training Initiative at the University of Miami
**CP** Continuous Progress
**EPCS** Eliot-Pearson Children's School
**IRB** Institutional Review Board
**KIWI** Kids Invent With Imagination
**PSEO** Post Secondary Enrollment Options
**STEM** Science Technology Engineering and Mathematics
**UMTYMP** University of Minnesota Talented Youth Mathematics Program
**U of M** University of Minnesota

# Chapter 1

# Introduction

On an even playing field, school aged girls and boys perform at the same level in *Science Technology Engineering and Mathematics* (STEM) subjects, and men and women perform the same in STEM disciplines as adults [Hill *et al.*, 2010]. Despite the demonstrable equality of potential and performance among men and women, debilitating gender stereotypes persist which deter girls from studying and eventually working in STEM. [Steele, 1997; Worth, 2010; Jenessa R. Shapiro, 2011; Hill *et al.*, 2010].

This thesis will explore the origin of cultural and educational bias relating to girls' presumed aptitude for STEM subjects and assess the impact of introducing computer programming and robotics concepts into early childhood education. Findings are presented regarding the gender based and social bias development of young boys and young girls around STEM interest and aptitude.

The hypotheses for study and classroom research were inspired by the interests and personal background of the chief researcher. The KIWI Robotics program developed by the DevTech Lab at Tufts University provided the foundation for the study[rfr, 2014]. A local elementary school provided an energetic team of 18 first-graders with little previous experience in computer programming and robotics.

The study concluded that gender based stereotypes, including self perceptions of the participating girls, can change after one short course of STEM related study during the first and second grade level. The findings include discussions of aptitude bias reduction as well as the strengthening of interest in STEM subjects. Considerations for further study are also presented.

# Chapter 2

# Motivations for Robotics in the Classroom

## 2.1 STEM in the Classroom

While science and technology have evolved rapidly in recent years, STEM education has progressed at a much slower pace, oftentimes being left out of schools altogether Duschl *et al.* [2007]; Bers *et al.* [2013]. As the proliferation of technology continues, more and more children are being exposed to technological tools at a young age. A 2011 study reported 53% of children age two to four, and 90% of children age five to eight use computes, and 25% of children engage in daily internet activity by the time they turn five [Rideout, 2011].

Despite the increasing technological exposure children have at home, the debate continues among educators as to the value of computer technology in the classroom. Some teachers argue that educational technologies are simply expensive substitutes for established teaching strategies, while others believe that technology enhances the learning experience when implemented with constructivist ideologies Kazakoff and Bers [2012]. Other teachers shy away from immersing their classrooms in technological activities because of their own lack of confidence in teaching and using computers [Davidson and Wright, 1994].

In 2009, the National Science Board produced a report for the Obama Administration seeking to increase the importance and prevalence of STEM concepts in early childhood education. The report stressed the importance of early exposure to technology to increase comfort with STEM concepts as children grow and develop [National Science Board, 2009].

## 2.2 Sequencing

*Sequencing*, the act of ordering a collection of things, is a crucial element in a child's early development [Epstein, 2007]. As a child learns to sequence she has the potential to learn, practice, and understand a wide range of behavioral and cognitive skills [Worth, 2010]. Children as young as 36 to 48 months can learn to follow simple one- or two-step sequences of direction, and at 48 months and older a child can start understanding the plots of simple stories [Virginia's Early Childhood Development Alignment Project, 2008]. For three to six year-olds, patterning is given emphasis in numerous content areas because it is accessible and interesting to young children, grows to undergird algebraic thinking, and supports the development of number, spatial sense, and other conceptual areas [Epstein, 2007]. Curricular goals from the states of Massachusetts and Virginia discuss the importance of sequencing in understanding foundational elements of linguistics and mathematics [Massachusetts Department of Elementary and Secondary Education MA DOE, 2008].

Because of it's critical role in the development of literacy and mathematical reasoning [Epstein, 2007], sequencing activities are frequently present in early childhood classrooms [Clements, 2003].

Computer programming combined with simple robotics provide students with an alternative and compelling medium with which to learn and practice sequencing [Bers *et al.*, 2014; Faculty of Education, 1996]. Computer programs consist of a sequence of instructions that the computer executes in order. Robots receive instructions from a computer program that is executed to *run* the robot. A robot will perform the sequence of instructions it reads from the program and behave only according to the program's predefined sequence of instructions. Exposure to programming language via a computer driven robot operating with simple commands can positively affect children's problem solving abilities [Faculty of Education, 1996].

Robots serve as a tangible and easily observable platform for children to observe and understand sequencing and sequence manipulation. In other words, robotics not only incite natural interest in the classroom, they bring to life the concept of sequencing via computer programming. Classroom activities that encourage children to solve problems via computer programming can provide positive motivation for children as young as kindergarteners to make choices and decisions, to alter their strategies, to persist at tasks, and can lead to higher scores on tests of critical thinking and problem-solving Bers *et al.* [2014]; Faculty of Education [1996].

## 2.3 Mathematics

The academic impact of computer programming and robotics reaches beyond sequencing into more complicated mathematics concepts. Most programming languages are imperative and perform as a sequence which can be simple and linear in nature, or as a more intricately crafted construct. For example, many languages include the concept of *loops*. Using loops a program can be written to repeat a given sequence of instructions multiple times. Loops not only give programs a greater range of functional possibilities, they also reinforce and teach mathematics concepts of counting and multiplication. Emerging curricular approaches at the middle school and high school level incorporate STEM subjects and specifically computer programming to extend and reinforce core mathematics education Center [2014].

## 2.4 Problem Solving

Programming and robotics tasks also can be structured to reinforce positive problem solving practices. Some elementary school curricula include the Engineering Design Process 287. The Engineering Design Process stresses the importance of planning, testing, reflecting, and modifying one's concept and design based on performance [Sullivan *et al.*, 2013; Beth Van Meeteren, 2010].

Robotics programming activities reflect this behavior. More often than not the first programmed sequence of commands written to solve a problem is imperfect. If the program is incorrect, when the program is written on a computer or uploaded to a robot to run, the test run will display unexpected behavior. The activities of analyzing the unexpected, brainstorming, and modifying the existing program follow the Engineering Design Process. The approach provides a context for rich mathematical, scientific, and technological conceptual development; and an inspiration for systems thinking, modeling, and analysis Bers *et al.* [2014]; Beth Van Meeteren [2010].

## 2.5 Social Interaction and Development

Under a social lens, the Engineering Design Process provides a curricular environment where failure is a positive and fun part of the learning. When activities are set up in a manner so that all groups of students are likely to *fail* on their first try, the activity helps foster a classroom setting in which students feel comfortable being uncertain or not knowing all of the answers Dr. Jean-Celeste M. Kampe [2012]. This creates a safe environment to experience failure and to learn from it, and it demonstrates to students that they can learn the skills needed to be successful problem solvers [Dr. Jean-Celeste M. Kampe, 2012].

Wartella and Jennings discuss that children more commonly ask their peers for assistance during an activity than their teacher or other adults in the classroom [Wartella and Jennings, 2000]. This increased social interaction among children in class positively impacts social and emotional development [Sullivan *et al.*, 2013; Bovey and Strain, 2008]. As children iterate through designs, their tendency to seek each other out for help fosters a positive collaborative atmosphere for learning.

The collaborative classroom environment also provides an open setting for children to develop and practice executive function skills including "organizing information, staying focused, strategizing, planning, and exercising self control" [Education Development Center, 2013]. Executive function skills have been known to be instrumental to success in school [Molfese *et al.*, 2011], yet traditional classroom activities are not designed specifically to support the development of these skills [Molfese *et al.*, 2011]. We contend computer programming and robotics activities fill this need while also teaching and reinforcing concepts in literacy and mathematics, thus making robotics both a productive use of classroom time and a mechanism for this study.

# Chapter 3

# Motivations for Study

## 3.1 Personal Experience

The following sections will discuss my experiences as a elementary and secondary student studying computer science. Although I was innately passionate and interested in STEM subjects, I interacted with many classmates and teachers who perpetuated the stereotype that boys are *better* at computer science and math than girls. As these experiences accumulated, I grew frustrated with the culture around girls in science and became inspired to understand why some of these stereotypes exist. My interests later expanded to working to change the academic culture to open STEM fields to more girls and women.

The following sections will discuss some of my experiences growing up with computer science and math and how these experiences and interactions motivated this study.

### 3.1.1 Elementary Classroom Experience

I grew up in an upper-middle class suburb of Minneapolis, Minnesota. I am the oldest of two children, have a younger brother, and I attended a public school with very little racial or socioeconomic diversity. Most of my peers were white, upper-middle class children from the my same community.

After kindergarten my parents decided to place me into a *Continuous Progress* (CP) education program at my elementary school. In CP, the teachers in two neighboring classrooms shared responsibility for a "family" of students spanning multiple grade levels. One teacher focused on a classroom of first through third graders, while the other teacher primarily taught third through fifth graders. Third grade students were assigned to a classroom based on achievement and maturity. CP provided students scaffolding to learn at their own rates, providing more assistance or more challenging advanced topics where necessary. For example, a second grade student could read at a third grade level and do math at a second grade level; seamlessly transitioning between levels as necessary.

In CP it was exciting to get to work with older students, so it was cool to be smart and to progress to more difficult material. In the CP family at school there was little emphasis placed on gender or grade level, instead the focus was on progress and learning.

In second grade I was designated as gifted and participated in Gifted and Talented programming provided by our school, which provided alternative curricular activities in addition to, and sometimes in place of normal classroom studies. Although CP provided extra challenges, as I progressed into older grades I started fighting against the ceiling of fifth grade opportunities and I wanted more. Gifted and Talented programs were a fun way to be challenged when material in the classroom was frustratingly repetitive and slow.

### 3.1.2 Fermi Math

Femi Off-The-Wall Math League began in 1999 and was designed by Minnesota School District 287 to engage elementary aged children in mathematics and technology enrichment activities [287].

The Fermi Program was offered to me as a series of field trip activities. The program included Gifted students from all city elementary schools, the majority of which were studying in traditional single-grade classrooms. At the time, CP was an available for just half of the student population at one of five public elementary schools in the city. This created a different social dynamic in the larger group of students than I was used to. Boys tended to gravitate towards each other and girls grouped together at separate tables. As the blocks were brought out for hands-on learning activities and challenges, the girls were much more hesitant to build than were the boys. Girl groups sat and thought and planned for awhile, whereas groups of boys dove right in, and buildings and machines immediately began to emerge as their creations.

Although I enjoyed thinking about Fermi Math and Blocks problems, the field trip experience was very uncomfortable and not particularly enjoyable for me. The awkward social dynamic between male and female students overrode my pure subject interest and I didn't have as much fun as I otherwise would have with groups of students from my elementary school's CP program.

The Fermi Math field trips were my first exposure to a gender divide in a STEM activity. While this experience did make me feel uncomfortable and feel inferior to the boys around me, I did not yet internalize any firm gender stereotypes or biases.

### 3.1.3 UMTYMP

In my school district, the CP program was only offered at the elementary school level. When I progressed to middle school, I quickly became frustrated with my single-grade classroom because the pace of math taught at school was much slower than I was used to in CP. Part way through sixth grade my math teacher gave me a math test to see if I could pass into seventh grade math. Even though the sixth grade and seventh grade math content was relatively easy for me to handle, I did not pass. I did not already *know* the math content that was yet to be presented in class, I simply yearned for a faster paced and more challenging math class.

A few weeks later my parents and I decided that I could to attempt to test into the *University of Minnesota Talented Youth Mathematics Program* (UMTYMP) program. UMTYMP allowed middle and high school aged kids to take classes at the *University of Minnesota* (U of M) with other UMTYMP students taught by U of M professors. The classes were held once a week for two hours and were taught at a college pace of one course per semester instead of the slower pace of middle and high school classes. UMTYMP accepted a very small percentage of students, so the students that did enter the program were all very smart, motivated, and excited about math. Parents were told that students would essentially cover "two to three years" of middle or high school math each year in UMTYMP. Students would attend one two-hour lecture and should anticipate an average of 12-14 hours of math home work per week. The program was not a mere acceleration or differentiation. It was a dramatic leap from traditional secondary mathematics schooling.

I joined UMTYMP as a seventh grade student and thoroughly enjoyed the challenge. In my second semester of UMTYMP I arrived at class early one day because I had questions about a homework problem. I approached a group of classmates in the hall and I asked if anyone could help me with the problem. I was met with laughter from the group, which consisted of all Asian boys, and one responded "of course you have questions about the homework because you're just a dumb white girl". I was getting a high grade in the class. I was not dumb. But I was a white girl. I was also a very self-assured, confident youngster so I was not shut down by the bullying. Nevertheless, this incident and many others like it during the program became commonplace. There was a clear stereotype that girls, especially white girls were not smart. The grade distribution constantly argued otherwise.

### 3.1.4 High School and Beyond

In high school I was required to take *Advanced Placement* (AP)[1] Computer Science because I had advanced through all of the mathematics class options offered by my public school.[2] I had no concept of what computer science was or what to expect in class.

On the first day of school in the fall I walked into class apprehensively, not knowing if I was in the right place in a room full of all boys. One of my classmates looked at me like I was lost and said to me, *"What the f**k are you doing here? You're a girl."* Thankfully, the teacher was also a woman and she laughed it off and assured the student that I was indeed in the right classroom. She laughed instead of punishing the student because his opinion was shared by most others in the room. I truly looked like I didn't belong. And I felt it too.

I stayed in the class because I was required to be there. After a few weeks of establishing myself as one of the top students in the class, my classmates began coming to me for help instead of looking down on me and assuming I didn't know what I was doing because I was a girl. After that point the rest of the year went by relatively smoothly, but the fact that I had to prove myself to my male classmates at the beginning of the year to earn their respect still left a sour taste in my mouth.

### 3.1.5 Tufts

My experiences in middle and high school had strong influence in shaping my own stereotypes about STEM fields. By the fall of my senior year of high school I had taken two additional college computer science classes, one at Normandale Community College, and one at the U of M through the Minnesota PSEO program.[3] After

[1] The College Board's AP program provides high school students the opportunity to receive college credit in introductory level college courses. The College Board administers AP Exams in 38 different subjects. Colleges and Universities across the country award various forms of credit to incoming freshman based on the scores on their AP Exams [Board, 2014].

[2] As a result of my participation in UMTYMP, by ninth grade I had already completed every math class offered by my high school. However, my high school counted graduation requirements by number of classes instead of level achieved. This meant that the "five years" of high school math I completed during UMTYMP in 7th and 8th grade didn't count towards graduation. I took my first computer science class because my high school decided to let it count as a math credit, and I needed additional math credits to graduate.

[3] Post Secondary Enrollment Options (PSEO) is a program that allows $10^{th}$, $11^{th}$ and $12^{th}$ grade students to earn college credit while still in high school, through enrollment in and successful completion of college-level courses. With traditional PSEO, these courses are offered on the campus of a postsecondary institution; some courses are offered online [Minnesota Department of Education].

successfully completing these two classes and AP Computer Science, I knew that I wanted to study computer science in college. However, I had a strong bias against the computer science culture in academia. My experiences fit the negative computer science stereotypes - computer scientists were antisocial, unhygienic, awkward boys who only cared about video games and science fiction - and these negative views became engrained in me.

When I looked at colleges I only applied to schools that had an engineering school *and* a college of liberal arts. I was convinced that I would never want to interact with these people, and that I needed to be at a college with students studying non-engineering majors so I could have friends with real social skills. My passion for the subject matter allowed me to sacrifice (I thought) my happiness in class to study something I was truly interested in, but I did not want to feel isolated in a school purely full of computer geeks. This led me to attend Tufts University's School of Engineering.

As I progressed through my first year at Tufts, my world view went through a radical transformation. Notably, I realized a stark difference between my bias towards engineering culture, and my experience as an engineer at Tufts. I made friends with my classmates, and I found a collaborative learning environment different from what I had experienced in high school or at the University of Minnesota.

Although I found myself to be very happy with the culture at Tufts, I wondered why some environments, such as my experience in AP Computer Science, felt so hostile towards women in computer science, where others like Tufts felt welcoming and supportive.

### 3.1.6 DevTech

In the fall of 2011 I took my first class connected with the DevTech lab working with the Scratch Jr. project.[4] In January of 2013 I started working with the KIWI Project and taught in a 2nd grade classroom in a local public school. During this teaching experience I was specifically studying differences in performance and participation of girls when the gender ratio of groups was varied.

During this ethnographic study I noticed that some students seemed to acknowlege gender engineering stereotypes and allow those stereotypes to dictate their participation and performance. I was curious to learn more about this phenomenon

[4] "ScratchJr is an introductory programming language that enables young children (ages 5-7) to create their own interactive stories and games. As children create projects with ScratchJr, they learn important design and problem-solving skills that are foundational for later success. ScratchJr supports the development of early numeracy and literacy, providing opportunities for children to use math and language in a meaningful and motivating context." [source: www.scratchjr.org]

and wanted to see if interaction with carefully planned KIWI curricula could dispel these stereotypes and foster a gender neutral, open-minded STEM learning community at school. This became the groundwork for my thesis study.

## 3.2 The Impact of Stereotypes on Performance

Throughout my experiences growing up with STEM subjects I noticed that as I got older, it seemed less *cool* to be a girl who enjoyed STEM coursework. Girls seemed much less interested in science and mathematics than boys did, and there was a clear stereotype that boys were much smarter at STEM subjects than girls were. There are many studies supporting my observations [Keller, 2012]. Research has shown that the psychological impacts of stereotypes are so strong that simply mentioning to girls that boys tend do better on a math test causes them to do worse than girls who take the same test without that taint [Hill *et al.*, 2010].

Stereotypes by definition are of cultural and social origin. For children, particularly young girls learning STEM subjects, gender-based stereotypes suggesting that boys and men are stronger in STEM commonly emanate from their friends, classmates, parents and even their teachers [Jenessa R. Shapiro, 2011]. The negative impacts on stereotypes by early elementary school teachers in the United States, greater than 90% of whom are female, include any individual bias they may project regarding girls' abilities in STEM, and further negative effects related to anxiety they may have from teaching mathematics. [Beilock *et al.*, 2009].

Gender-based stereotypes involving STEM subjects commonly begin to take hold in early childhood and can adversely impact girls' performance and interest in mathematics as a result of "stereotype threat." [Steele, 1997], [Jenessa R. Shapiro, 2011]. Stereotype threat can materialize when an individual perceives themselves to be a member of a group for which a stereotype exists [Steele, 1997]. These threats can take the form of a self-as-source stereotype where a girl internalizes gender-retated math attitudes, or an other-as source stereotype that emerges as a function of perception of how other's may assess her performance [Jenessa R. Shapiro, 2011]. In both cases the individual impacted by the stereotype threat feels increased anxiety and burden in an academic or assessment setting which leads to lower performance.

It is not the low performers who are at the greatest risk of adverse impacts. Stereotype threat research points to a different population as being most at risk for the undermining nature of stereotypes: high ability and high achieving individuals [Jenessa R. Shapiro, 2011]. Because stereotype threat is a concern regarding how ones performance will be interpreted, stereotype threat emerges when people care about a particular domain and their performance in the domain [Steele, 1997].

Steele, one of the researchers on the forefront of investigation on this subject, has shown that in order to be successful in school, and to combat the effects ot potential stereotype threats, a child must include achievement as a part of his or her own self-definition [Steele, 1997]. In my experience, girls around me did not define themsleves based on their achievement level in STEM subjects, and as demonstrated by Steele's research, they did not typically perform at a high level, and they may have been negatively impacted by stereotypes.

Jennifer Steele discusses the concept of *stereotype stratification*, "the process of cognitively viewing oneself as a member of a subgroup to which the stereotype does not apply." Stratification can help an indvidual subject to stereotype threat to lessen or avoid the hindering effects of stereotype. In her research she saw girls in elementary school who had an explicit understanding of a stereotype about *men's* and *women's* mathematical ability, but stratified the stereotype away from *boys* and *girls*. [Steele, 2003].

Researchers in this feild have discovered two separate ways in which people stratify or divide large groups to morph the groups upon which they apply certain steretypes. *Subtyping* involves removing members of a group for whom a stereotype does not apply and categorizing them as exceptions [Maurer *et al.*, 1995]. In contrast to subtyping, *subgrouping* involves the process of identifying a subset of a larger group that either fits or does not fit the stereotype. In both subtyping and subgrouping, an individual lessens their personal association with the stereotype and consequently reduces the level of stereotype threat they encounter.

J. Steele discusses that stereotype stratification only occurs when a person sees a negative in-group stereotype; i.e. a person associates with a group for which a negative stereotype is applied. Steele suggests that a person will then "use one of the subgroups to which he or she belongs as a means of subtyping himself or herself away from the stereotype" [Steele, 2003]. In her research, J. Steele found that girls in elementary school acknowledged a strong stereotype that men perform with a higher mathematical ability than women, even though girls and boys perform at a gender-neutral level [Steele, 2003].These findings demonstrate that some degree of beneficial stratification tends to occur in early childhood, however the substantial body of research shows that social factors, likely including increasing stereotype threat for girls in STEM has a substantial impact beyond the early school years.

Steele's observations about stereotype stratification and the interplay with stereotype threat and the impacts on girls in STEM were the foundation for the research presented in this thesis.

# Chapter 4

# Research Questions

In an effort to expand on past studies about girls and mathematics, my focus was to extend the research into other areas of technology and engineering including computer science. I wanted to better understand the stereotypes that exist in elementary aged children, but also investigate how those stereotypes could change after a positive curricular expereince with engineering. With this in mind, I developed a two-part study utilizing robotics technology developed by the DevTech Lab at Tufts. First, my study would look at what stereotypes exist prior to any classroom introduction to robotics or engineering technology. Second, I would teach a unit on robotics with the class and assess what stereotypes exist after the curricular exploration of robotics.

## 4.1 Study I: Impacts of Gender-Based Engineering Stereotypes on Robotics Performance

**Research Question I** How do the stereotypes that young girls hold about engineering differ from those of young boys, and how do these sets of stereotypes impact the children's performances with robotics in the classroom?

### 4.1.1 Hypotheses for Study I

**Hypothesis I** Both boys and girls will group engineering-related careers with males more often than females.

**Hypothesis II** Girls who have no explicit male-engineering bias will perform better in the classroom.

**Hypothesis III** Both boys and girls will view boys as having greater interest in engineering topics than girls.

**Hypothesis IV** Children who perceived themselves to be a part of a group with positive interest and ability in engineering topics will perform at a high level in class and will show more interest and enjoyment during each lesson.

**Hypothesis V** Children who perceived themselves to be a part of a group with negative interest and ability in engineering topics will perform at a lower level in class and will show negative interest and little enjoyment during lessons.

## 4.2 Study II: Impacts of Robotics Performance on Gender-Based Engineering Stereotype Change

**Research Question II** Do performance and happiness during the robotics unit predict change in gender-based engineering stereotypes?

### 4.2.1 Hyptotheses for Study II

**Hypothesis VI** Performance in robotics will not have a correlation to gender.

**Hypothesis VII** Children who performed well on robotics assessments will group engineering-related careers to their gender.

**Hypothesis VIII** As a whole, there will be less difference in the implicit and explicit perception of boy's interest and ability in engineering topics as compared to girls' interest and ability in engineering topics after the robotics unit.

# Chapter 5

# KIWI Robotics

## 5.1 Overview

KIWI Robotics is robotics kit designed and built by the DevTech Research Group at Tufts University, funded by the National Science Foundation (NSF Grant No. DRL-1118897, DRL-0735657). KIWI was created specifically for use in early childhood (pre-Kindergarten to 2nd grade) classrooms [Bers *et al.*, 2013]. Each kit consists of robotic parts that are programmable using the CHERP programming interface also developed by the DevTech Group. The kits were devloped in such a way that a range engineering, robotics, and programming tasks could be taught across a rangefrom simple sequencing tasks, to complicated sensors and loops.

## 5.2 CHERP

The CHERP programming interface (NSF grant No. DRL-0735657) was designed as a tool for young children to program robots [Bers *et al.*, 2013]. CHERP consists of multiple commands that connect in a certain order to create functional robotics programs. The CHERP interface allows a child to create simple sequential programs, and create more complicated programs using loops, sensors, and robotic outputs such as sound and light [Sullivan *et al.*, 2013; Flannery and Bers, 2013].

CHERP consists of a hybrid tangible-graphical programming environment. This means that CHERP programs can be created using a physical and a computer interface. Physically CHERP programs are created with colored blocks. Each block represents one single command and connects to other blocks to make complete programs. The computer interface consists of a set of icons with the same commands as the blocks that can be dragged and dropped to connect like puzzle pieces creating a program. Both interfaces are shown below. KIWI robots can read programs by

| Control Flow | Movement | Sensing |
| --- | --- | --- |
| Begin | Forward | While Dark |
| End | Backward | While Light |
| Begin Repeat | Turn Right | While Near |
| Left Repeat | Turn Left | While Far |
| If Dark | Shake | Wait For Clap |
| If Light | Spin | Light On |
| If Near | Beep | Light Off |
| If Far | Sing | |

Table 5.1: CHERP Commands

scanning barcodes on each block in order, or by connecting to the computer's USB port.

### 5.2.1 Block Interface

CHERP blocks connect to each other to form program sequences. Control flow blocks that can take parameters, such as "If" and "While" are longer and contain a velcro section to attach parameters.


Figure 5.1: Sample program created with CHERP blocks

### 5.2.2 Computer Interface

The CHERP computer interface allows children to build programs using physical on-screen blocks that can be clicked and dragged to build programs in the center of the screen. Blocks "snap" into place when they connect, and can only be connected in syntactically correct ways to reinforce programming concepts.


Figure 5.2: Sample program created with CHERP blocks and shown on computer interface

## 5.3 KIWI Robots

### 5.3.1 Robot Parts

KIWI Robots come disassembled and contain a collection of moving parts, sensors, and a light output. The robots are designed to be easily assembled in multiple different ways, and to be easily accessorized with the incorporation of art materials typically found in classrooms.

| Part | Quantity |
|---:|:---:|
| Chassis | 1 |
| Side Motor | 2 |
| Top Motor | 1 |
| Turn Table | 1 |
| Stage | 1 |
| Corner Post | 4 |
| Wheel | 2 |
| Lantern | 1 |
| Distance Sensor | 1 |
| Clap Sensor | 1 |
| Light Sensor | 1 |

Table 5.2: Contents of a KIWI Robotics Kit

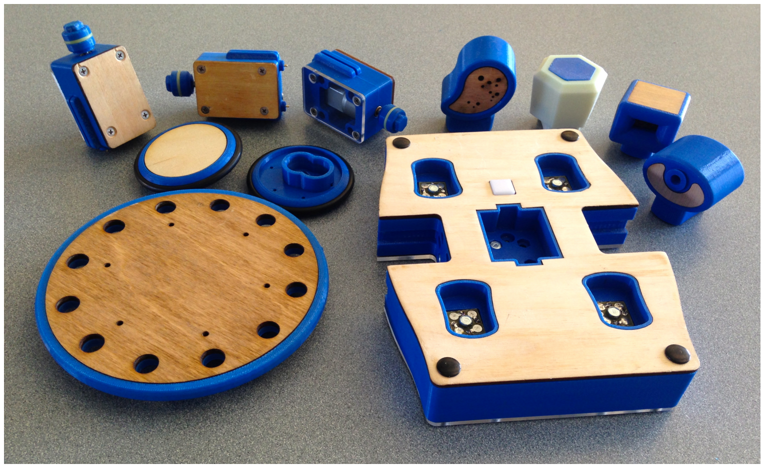

Figure 5.3: Parts found in a KIWI Robotics Kit

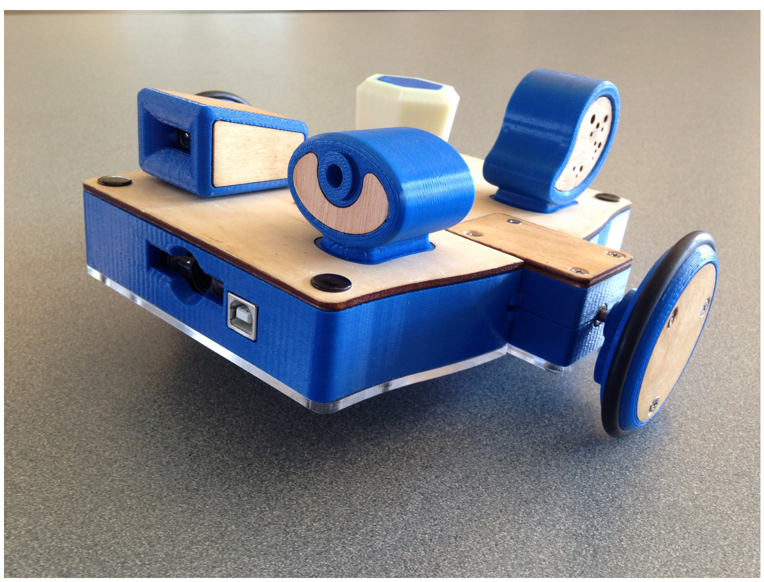

Figure 5.4: Assembled KIWI Robot

### 5.3.2 Robots for All Levels

KIWI was designed with progressive learning in mind. Early learners can explore a basic KIWI Robot with basic motors and wheels. As more robotic, programming, and building concepts are introduced, children can explore more complicated robots involving sensors, the turn table, and the stage.

### 5.3.3 Current Study

In this study, KIWI Robots are used solely with the CHERP block interface. Beginning lessons introduce basic control flow and movement blocks. Advanced repeats and sensors are added as concepts are grasped.

# Chapter 6

# Curriculum

## 6.1 Overview

This curriculum was deisgned specifically for the 1st and 2nd grade classroom at *Eliot-Pearson Children's School* (EPCS). Curricular ideas were modified from previous curricula from the first version of KIWI Robots, the DevTech Summer Institute, and other researchers in the DevTech Lab. [1] The curriculum was designed to integrate programming and robotics concepts with social studies and music topics that were currently being studied in class. This strategy brings engineering, robotics, and computer programming out of a stereotypically isolated environment and allows students to think about engineering concepts in conjunction with other subject areas giving each lesson a greater sense of fun and purpose.

## 6.2 Lesson I: Introduction to Programming and Robots

The purpose of the first lesson was to dispel common myths about robots, and to introduce the children to KIWI and CHERP through a series of class games and small group activities.

### 6.2.1 Brainstorming: What is a robot?

This lesson began with a class brainstorming sesson asking the question: *"What is a robot?"*. The researcher wrote responses down on an easel so everyone in the class could see the list of responses. There were no "right" or "wrong" answers, some responses contradicted each other and children were prone to verbally disagree with each other. When this happened, the researcher addressed the contradictions by

[1] Mollie Elkin, Ji-Sun Ham, Amanda Strawhacker, Amanda Sullivan

asking if there were possibly different kinds of robots. Once the class was out of ideas, we moved on to the next activity.

### 6.2.2 "Jump if It's a Robot"

The researcher had all of the children and teachers stand. The researcher then held up a picture and asked each child to jump if he or she thought the picture displayed something that was a robot. Pictures ranged from cars to humanoids to refrigerators to beds to dogs.[2] As one may expect, some pictures had unanimous classroom agreement or disagreement on whether or not the picture depicted a robot, but most pictures fell into a grey area of maybe a robot, or maybe not a robot.

### 6.2.3 Brainstorming Redux

During the Jump if It's a Robot activity, the list of robot characteristics developed during the brainstorming session was visible to all of the children. Following the activity we discussed the list again as a class leaning towards the consensus that there is no single description of a robot.

### 6.2.4 Introduction to KIWI Parts

The researcher then introduced KIWI to the students.

The discussion ended by asking the class how robots know what to do. Children suggested *"we tell them what to do"*, *"we give them instructions"*, and *"they have programs."* This segued into an introduction of the CHERP language.

### 6.2.5 Program Your Teacher

The researcher explained that we write programs for our robots using CHERP. The children were then told that robots can do very complicated things, but they will only do *exactly* what we tell them to, nothing more, and nothing less!

Basic CHERP commands "Begin", "End", "Forward", "Backward", "Turn Right", "Turn Left", "Spin", "Beep", and "Sing" were printed on large cardboard pieces. Basic program syntax was explained and the class came up with a program for their teacher. Once the program was complete, the teacher acted the program out as the students said the program out loud. This activity was repeated multiple times programming different adults in the classroom.

[2] Full list of pictures included in the Appendix

### 6.2.6 KIWI Exploration

The final Program Your Teacher program was then created using physical CHERP blocks. The researcher scanned the program with the KIWI robot used previously as a demonstration. Then we ran the program on the KIWI and said each command as the robot acted out program.

The remaining time in the lesson was used for free exploration of KIWI kits and CHERP basic blocks as groups.

## 6.3 Lesson II: Hokey Pokey and Sensors

The purpose of this lesson was to explore of creation of simple sequential programs by programming the Hokey Pokey Dance for robots. Additionally, this lesson introduced children to the concepts of sensors and sensor sequencing. Three new blocks were utilized, the "Wait for Clap" block, the "Light On" block, and the "Light Off" block.

### 6.3.1 What is a sensor?

To begin class we reviewed the parts of KIWI Robots and played a few rounds of Program Your Teacher.

The researcher introduced sensors by asking the class what senses humans have and explained that so far our robots don't have any senses. The classroom teacher uses a bell to get the student's attention. The researcher introduced the KIWI Sound Sensor and explained and demonstrated it's functionality to the students with the "Wait for Clap" block. The researcher also introduced the light output as the second robotic output, and left the students to explore the "Light On" and "Light Off" blocks.

Then we transitioned by talking about dancing and dances that the class had learned in the weeks prior to the robotics unit. We talked about how the dances had order and steps just like programs do for robots.

I then taught the class the Robot Hokey Pokey:

*You put your robot in, you put your robot out*
*You put your robot in, and you shake it all about*
*You do the hokey pokey and you turn your robot around*
*That's what it's all about!*

### 6.3.2 Hokey Pokey Program

Students were split into groups and given the task to program their robots to do the Robot Hokey Pokey after a student clapped to tell the robot to start. The Dance translates into the following program:

Begin, Wait for Clap, Forward, Backward, Forward, Shake, Spin, Sing, End.

Groups were also permitted to explore adding light output to their dance. After each group finished, everyone brought thier robots to a sharing area and performed the dance with their robots.

## 6.4 Lessons III-IV: Paper Challenges

The purpose of these lessons were to review sequential programming concepts and introduce the concept of repeats.

### 6.4.1 Review of Programming Concepts

This lesson began with two quick Program Your Classmate games to reveiw programming concepts. Then to introduce repeats the class brainstormed activities they did multiple times in a row - brushing teeth back and forth multiple times, etc. I explained that sometimes we want robots to do things more than one time before the move on to the next action.

Then the "Repeat" and "End Repeat" blocks and syntax were introduced with number parameters. The following sample program equivalents demonstrating repeating forward were used as an example:

Begin, Forward, Forward, Forward, Forward, Foward, End.

Begin, Repeat, 5, Forward, End Repeat, End.

### 6.4.2 Paper Challenges

The Paper Challenges activity included a series of maps drawn out on large pieces of paper. The first challenges involved review of basic sequencing concepts and required the following program for solution:

Begin, Forward, Forward, Turn Right, Forward, End

The next challenge was designed to reinforce the engineering design process concept of testing and reworking a solution. The map displayed a straight path, a spin direction, and then a path to the left. Groups would generally try the following:

Begin, Forward, Forward, Spin, Turn Right, Forward, End

The spin instruction actually caused the robot to spin 450 degrees resulting in a rightward facing robot. Thus, the above program would cause a robot to drive forward twice, spin and end up facing right, turn right to face backwards and then drive forward once. Groups modified their programs to the following to solve the challenge:

Begin, Forward, Forward, Spin, Backward, End

The third challenge was another derivation of the forward and turn that reinforced the use of repeats. The challenge required the robot to go forward twice, then beep, then turn left, then drive forward once. The correct solution to this program is:

Begin, Repeat, 2, Forward, End Repeat, Beep, Turn Left, Forward, End.

The next challenge served as a simple review of sensors to prepare for the final challenge. The challenge was for the robot to drive forward until it reached the wall. The correct solution to this program is:

Begin, Repeat, While Far, Forward, End Repeat, End

The final challenge paired sensors with the introduction of the concepts of Ifs to groups who had mastered repeats and sequencing. The challenge had a straight path with a box with a question mark in the middle that said “If there is a monster, sing to scare it, then continue to drive forward”. This challenge resulted in the following program:

Begin, Forward, If, Near, Spin, Forward, End.

## 6.5 Lessons V-VI: Final Project – Dances Around the World

The final project incorporated new robotics and programming skills with what the children had learned in class about global cultures and dances around the world. Each group was assigned a different dance and was tasked to program their robot to dance their assigned dance (with music!) - groups were encouraged to use repeats and sensors as necessary.

# Chapter 7

# Research Methods

## 7.1 Participants

A total of 18 first grade students participated in this study. The students came from varied ethnic backgrounds, most were from middle to upper-class families and all were enrolled in a private laboratory school associated with Tufts University in Medford, Massachusetts. Consent for the children's participation in the study was obtained from the *Institutional Review Board* (IRB) of Tufts University, the IRB of EPCS, the principal of EPCS, the teacher of the classroom, and each child's parents. The study was conducted by the researcher on school premises in a both a back area of the classroom with school representative or teacher present at all times, and in the main teaching area of the classroom.

## 7.2 Researcher

The researcher is a 21 year-old female senior undergraduate student at Tufts University's School of Engineering majoring in computer science and mathematics. The researcher has taken background coursework in early childhood technologies, robotics, and curriculum development. Additionally, the researcher has assisted in other classroom studies and curriculum development with the DevTech Research Group. Required *Collaborative Institutional Training Initiative at the University of Miami* (CITI) training for work with children was completed prior to investigation.

## 7.3 Influence of Past Studies

The implicit and explicit measures I used for this study were adapted from Steele's study regarding mathematics stereotypes in elementary-aged children [Steele, 2003].

## 7.4 Study Phases

The study consisted of three phases of testing, and four different types of assessments. The pre-testing phase took place prior to the start of any in-class robotics instruction. The pre-testing phase consisted of a series of assessments for implicit and explicit gender-based engineering stereotypes. This was followed by a teaching phase in which robotics was taught in the classroom during eight 45-minute sessions. During the teaching phase, happiness assessments and performance assessments were implemented to track enjoyment and progress. Happiness assessments took place after each lesson, and "Solve-It" challenges to assess robotics knowledge and learning were conducted after the last robotics lesson. The study concluded with post-testing in which the same assessments for implicit and explicit gender-based engineering stereotypes administered during pre-testing were again given to each participant.

## 7.5 Phase I: Pre-Testing

### 7.5.1 Procedure for Implicit and Explicit Gender-Based Engineering Stereotype Analysis

Each child participated in a 10-minute session conducted by the researcher in a back area of the child's classroom. This assessment was conducted both during pre and post-testing.

### 7.5.2 Implicit Stereotype Assessment

Prior to the assessment, the classroom teacher introduced the researcher to the class and explained that she would be doing activities one-by-one with each child. The researcher pulled each child out from a classroom activity and brought the child to another area of the classroom for the assessment. Once seated, the researcher introduced herself to the child. Then each child was told that they were going to do a series of activities to get to know them better before the researcher came into the classroom as a guest teacher.

The child participating in the assessment was then told that the first task had to do with sorting pictures into two piles, one on the right side of the desk and one on the left side of the desk. The researcher told the child that she would place the first 4 pictures into piles for the child, and that the child would then place the remaining pictures into the correct piles.

During the training phase of this assessment, the researcher showed each child pictures of a man, a woman, a boy, and a girl and placed the pictures in piles according to their gender. The boy and the man grouped in one pile, the woman and the girl grouped in the other pile. Half of the study participants saw the male pile on the left, and half of the participants saw the male pile on the right.

The researcher then presented the participant with 16 additional pictures  8 males, and eight females  one at a time, and instructed the participant to place the picture in its correct group. Each child was corrected if they placed a picture in the incorrect group. The task was repeated if the researcher felt the participant needed additional practice to understand the rational for sorting into the two groups.

Following successful completion of the training phase, each participant was told that the researcher would be presenting him or her with another set of pictures that did not have a correct grouping, and that the researcher just wanted to know which pile the participant thought the image fit best in. Each child was further instructed that he or she did not have to answer if he/she felt uncomfortable answering and they could skip to the next image.

The images consisted of eight different professions. Each image had a picture of a male and a female doing the profession, and a label of what the pictures were depicting. Four of the images were chosen as engineering professions (computer engineer, robotics engineer, mechanical construction engineer, chemical engineer), and four of the images were chosen as neutral non-technical professions (police officer, teacher, astronaut, doctor). The researcher recorded the responses of each of the testing images.

### 7.5.3 Explicit Stereotype Assessment

Directly after completion of the sorting task, participants completed two tasks to measure explicit awareness of gender-based engineering stereotypes. The first task was designed to measure perception of stereotypes about gender-based engineering ability. The participant was shown an image of 5 test tubes with various levels of liquid in them ranging form empty to full (empty, $^1/_4$ full, $^1/_2$ full, $^3/_4$ full, full) and labeled "Not Very Good", "Sort of Not Good", "Sort of Good, but also Sort of Not Good", "Sort of Good" and "Very Good" respectively. The researcher read the labels and pointed to the corresponding test tubes to the child, then told the child that she would be asking him or her a series of questions and the researcher instructed the child to point to the test tube that best represented his/her answer to the question [1] The participant was told that there were no right or wrong answers to any of the questions and that they could skip to the next question if the participant was uncomfortable answering.

The researcher asked the child two practice questions to familiarize the participant with the scale. Then the researcher proceeded to ask six testing questions: "How good are most boys at robotics?", "How good are most girls at robotics?", "How good are most boys at computer programming?", "How good are most girls at computer programming?", "How good are most boys at engineering and building?", and "How good are most girls at engineering and building?" Half of the participants were asked questions about boys before questions about girls, and the other half of the participants were asked questions about girls before questions about boys. The researcher recorded responses to each of these questions.

The second task was designed to measure perception of stereotypes about gender-based engineering interest. For this task the participant was presented with an image of four smiley faces ranging from very sad to very happy, and labeled "Didnt like it at all", "Kind of disliked it", "Kind of liked it", and "Loved it" respectively. The researcher read the labels and pointed to the corresponding happy faces and instructed the child that they were going to be asked questions in a similar manner. The participant was instructed to point to his/her response as in the previous assessment and was instructed that the participant could skip a question if he or she felt uncomfortable answering.

The researcher asked the child two practice questions to familiarize the child with the scale and then proceeded to six testing questions. The participant was asked, "How much do most boys like robotics?", "How much do most girls like robotics?", "How much do most boys like computer programming?", "How much do most girls like computer programming?", "How much do most boys like engineering and building?", "How much do most girls like engineering and building?" As in the previous task, half of the participants were asked questions about boys before questions about girls, and the other half of participants were asked questions about girls before questions about boys. The researcher recorded the responses to each of these questions.

[1] It is observed that the images utilized in this explicit stereotype assessment were test tubes which could correlate to a science bias. The images are included in the appendix.

## 7.6 Phase II: Performance and Happiness Assessment

### 7.6.1 Happiness Assessment

Following each lesson, children were given a worksheet with a likert-style scale of 4 happy faces mirroring the one from explicit stereotype assessment. The children were then asked how much they liked the robotics activity in class. Each child circled, or colored in the happy face corresponding to his or her response. The researcher gathered the worksheets and recorded the responses of each of the students.

### 7.6.2 Procedure for Solve-Its Challenge

At the conclusion of the curriculum, the researcher asked each child to complete a sequence of Solve-Its assessments to evaluate comprehension of various programming concepts. The Solve-Its were previously developed by the DevTech Research group and were modified to reflect the concepts taught during this curriculum.

In each assessment the children were asked to play a game in which the researcher told a story about a robot performing a sequence of actions, and then gave the children paper icons of familiar programming blocks. The children were then supposed to arrange the icons given to design a program for the robot to behave in the way described in the story. Each Solve-It task was designed to assess different programming concepts that were taught throughout the curriculum.

### 7.6.3 Solve-It 1: Baking a Cake

The first Solve-It was designed to assess basic sequencing concepts. The researcher told the following story about baking a cake:

> Now we are going to make a robot that will help me bake a cake for the birthday party! First I want my robot to turn on. Next, I want it to shake all the flour and sugar into a big pan. Then, the robot is going to mix all the ingredients up by stirring a spoon around in the pan. Now its time to push the cake pan straight ahead into the oven. When the cake is ready, the robot will make a noise, like BEEP! Last, I want the robot to turn off.

The children were then given strips of paper to tape icons to, and icons corresponding to the following commands: BEGIN, SHAKE, SPIN, FORWARD, BEEP, END. The children arranged their given icons onto strips of paper and raised their hand when they were ready for a research assistant to tape their icons down for submission.

### 7.6.4 Solve-It 2: Microwave

The second Solve-It was designed to assess basic understanding of repeats and repeat syntax. The researcher told the following story about a microwave-robot:

> In this game, my robot is actually a microwave! Have you ever seen a microwave spin food around to heat it up? First, I want my microwave to turn on. Then I want it to spin and heat up my food, and keep doing it for four seconds. After four seconds, I want the robot to stop spinning, and to make a noise  Beep!  to let me know that my food is ready! Last, I want the microwave robot to turn off.

For this solve-it, Children were given the following icons: BEGIN, REPEAT, 4, SPIN, END REPEAT, BEEP, END.

### 7.6.5 Solve-It 3: Extra Beep

The third Solve-It was designed to assess deeper understanding of repeats. For this challenge children were told:

> This game is a little bit tricky. I have a robot, and I just want it to make a noise four times. It needs to turn on first, and then beep four times. After that, the robot needs to stop beeping, and then turn off. BUT! There are extra blocks that I am about to give you. You do not need to use all of these pieces of paper, and some of them will not help you make a program to make my robot beep four times.

Children were given the following icons: BEGIN, REPEAT, 4, BEEP, BEEP, BEEP, BEEP, END REPEAT, END. We wanted to observe whether students could successfully program the robot using only one of the BEEP icons, (BEGIN, REPEAT, 4, BEEP, END REPEAT, END vs. BEGIN, BEEP, BEEP, BEEP, BEEP, END.)

### 7.6.6 Solve-It 4: Sensors

The final Solve-It was designed to assess the children's understanding of repeats with sensors. For this challenge children were told the following story about a school bus robot:

> This game is a also little bit tricky. I have a school bus robot full of kids who need to get to school! I need the school bus to turn on, and

> drive forward until it gets to school and then turn off. BUT! Just like last time, there are extra blocks that I am about to give you. You do not need to use all of these pieces of paper, and some of them will not help you make a program to drive the robot school bus to school.

Each child was given the following icons: BEGIN, REPEAT, UNTIL NEAR, UNTIL FAR, FORWARD, END REPEAT, END. We tested to determine whether the children were able to use the UNTIL NEAR block in stead of the UNTIL FAR block.

Results from each solve-it were gathered and the strips of paper were later processed and recorded on a spreadsheet.

# Chapter 8

# Results and Discussion

## 8.1 Excluded Data

One male participant and one female participant did not feel comfortable completing the picture-sorting task during pre-testing, so their data is excluded from tests comparing pre and post testing.

## 8.2 Gender Bias of Teacher

All lessons were taught and assisted by female teachers. All regualr teachers and classroom helpers were also women. There is a possibility that teacher gender influenced results.

## 8.3 Study I: Impacts of Gender-Based Engineering Stereotypes on Robotics Performance

**Research Questions of Study 1** How do the stereotypes that young girls hold about engineering differ from those of young boys, and how do these sets of stereotypes impact the children's performances with robotics in the classroom?

### 8.3.1 Indirect Stereotype Measure Pre-testing

**Hypothesis I** Both boys and girls will group engineering-related careers with males more often than females.

The first hypothesis postulated that both boys and girls would group engineering pictures with males more often than females in the pre-testing phase. To test this hypothesis, each child was given a score from 0 to 4 based on the number of engineering career pictures the child placed into the female pile. Three one-sample t-tests were performed: one on the data resulting from the eight girls participating in pre-testing, one on the data resulting from the eight boys participating in the test, and one on the class as a whole. For each of the t-tests, the hypothesis mean was $\mu_0 = 2.0$ representing the mean if pictures were randomly placed in piles. The female one-sample t-test rejected the null hypothesis at the $\alpha = 0.05$ level with a t-statistic of $t = 0.68$ and a p-value of $p = 0.258$. This statistic was not significant. The male one-sample t-test also had an insignificant p-value.

Although the girls and the boys showed no significant male-engineering association, one-sample t-test for the class as a whole accepted the null hypothesis with a p-value of $p = 0.036$ at the $\alpha = 0.05$ level displaying that as a class there is no consistent stereotype recognition.

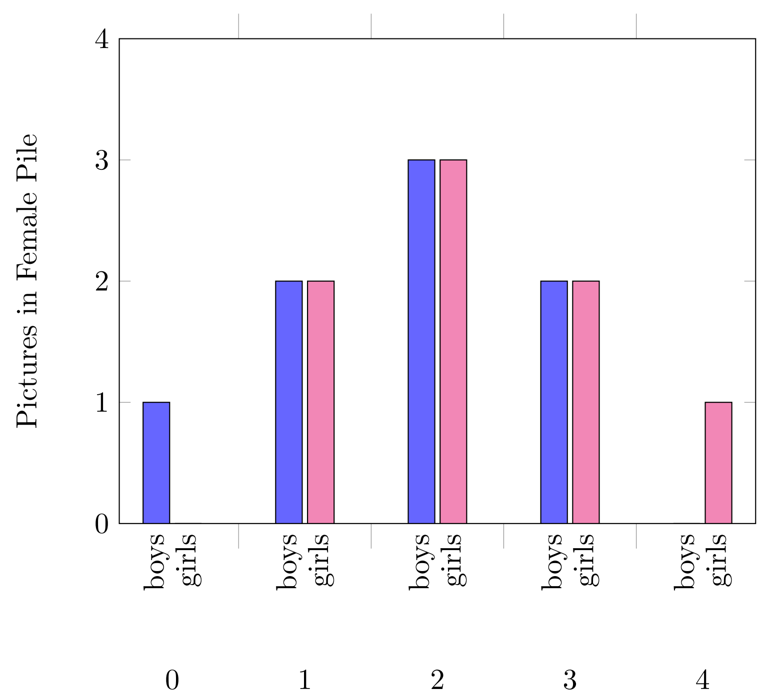


Figure 8.1: Direct Stereotype Measure Results from Pre-Testing

### 8.3.2 Direct Stereotype Measure

**Hypothesis II** Both boys and girls will view boys as having greater interest in engineering topics than girls.

Hypothesis two stated that both boys and girls would perceive boys to have a higher level of interest and ability to succeed in engineering topics. As seen in the tables below, pre-testing data supports the hypothesis. Out of 49 questions asked, 6% of responses recorded girls with higher interest than boys, 57% of responses recorded boys with higher interest than girls, and 35% recorded gender-neutral interest. For the ability measure, out of 54 questions asked, 11% of responses recorded girls with higher ability than boys, 44.5% boys recorded boys with a higher ability than girls, and 44.5% recorded gender-neutral ability.

**Hypothesis III** Girls who have no explicit engineering-male bias will perform better in the classroom than girls with explicit engineering-male bias.

To test this hypothesis, girls who completed the pre-assessment were divided into groups based on their explicit engineering-male bias based on the explicit phase of pre-testing. All participants were given a Total Difference score based on subtracting their responses to explicit interest and ability questions about boys from their responses to explicit interest and ability questions about girls. Participants with a Total Difference score between $-1$ and 1 were determined to have no explicit engineering-male bias ($n = 5$). All other participants had Total Difference scores with engineering-male bias ranging from $-11$ to $-3$ ($n = 4$). A paired t-test with each participant's Total Difference Score and Normalized Success Score was performed and decidedly rejected the hypothesis. Inspecting the data more closely we can see that indeed there is no decisive trend between performing above average $y = 0.845$ and having an explicit male-engineering bias. Of the four girls who performed above average in this sample 50% had no male-engineering bias, and 50% had male-engineering bias.

| | How much do most like computer programming? | | How much do most like robotics? | | How much do most like engineering and building? | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Boys | 3.5 | 0.5345 | 3.4444 | 0.8819 | 3.4444 | 0.8819 |
| Girls | 2.7779 | 1.0929 | 3.5556 | 0.7265 | 2.4444 | 0.7265 |

Table 8.1: Explicit Ratings by Girls for Interest Scale

| | How much do most like computer programming? | | How much do most like robotics? | | How much do most like engineering and building? | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Boys | 3.4444 | 0.7265 | 3.6667 | 3.125 | 3.7778 | 2.5 |
| Girls | 2.5714 | 0.7868 | 0.7071 | 0.8345 | 0.8345 | 0.7559 |

Table 8.2: Explicit Ratings by Boys for Interest Scale

| | How good are most at computer programming? | | How good are most at robotics? | | How good are most at engineering and building? | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Boys | 4.3333 | 0.7071 | 4.0 | 0.8819 | 4.2222 | 1.2019 |
| Girls | 3.4444 | 1.3333 | 3.8889 | 1.1667 | 4.3333 | 0.7071 |

Table 8.3: Explicit Ratings by Girls for Ability Scale

| | How good are most at computer programming? | | How good are most at robotics? | | How good are most at engineering and building? | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Boys | 4.4444 | 0.7265 | 4.5556 | 0.7265 | 4.4444 | 0.8819 |
| Girls | 3.8889 | 1.0541 | 3.6667 | 0.7071 | 3.7778 | 1.0929 |

Table 8.4: Explicit Ratings by Boys for Ability Scale

| | Correctness | Sequencing | Basic Repeats | Repeat Syntax | Repeats and Sensors | Max Score |
|---|---|---|---|---|---|---|
| Baking a cake | X | X | | | | 2 |
| Microwave | X | X | X | X | | 4 |
| Extra Beeps | X | X | X | X | | 4 |
| Forward to Wall | X | X | X | X | X | 5 |

Table 8.5: Four Solve-It Tests were given during the Performance Testing session. Solve-Its were designed to test a range of topics, *correctness, sequencing, basic repeats, repeat syntax, and repeats with sensors.* Each Solve-It test was given a Max Score based on the number of categories that it tested for. Each student's scores were compiled into one Success Score with a Maximum Success Score of 4.0 and then normalized so Max Score was 1.0 or 100%.

**Hypothesis VI** Children who perceived themselves to be a part of a group with positive interest and ability in engineering topics will perform at a high level in class and will show more interest and enjoyment during each lesson.

To test this hypothesis the Total Difference Scores were examined to determine which girls had female-engineering bias and which boys had male-engineering bias. Four children were examined further. Each of these children were male with Total Difference Scores less than $s = -2$. Performance Scores for each of these children were then examined for correlation. As seen in the following plot, the hypothesis can be rejected for correlation between larger bias to higher performance.

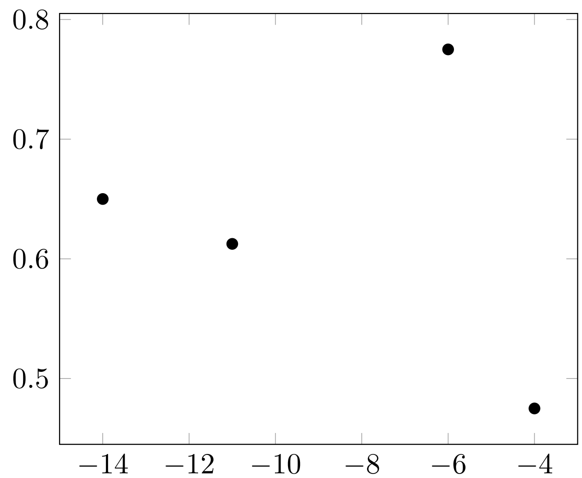


Figure 8.2: Total Difference Score vs. Performance Score for Select Students

**Hypothesis V** Children who perceived themselves to be a part of a group with negative interest and ability in engineering topics will perform at a lower level in class and will show negative interest and little enjoyment during lessons.

There was only one child who perceived herself to be part of a group with negative interest and ability in engineering topics, and therefore data was insufficient to validate this hypothesis. The child identified had a Total Difference score of $s = -14$ representing a very strong male-engineering bias. She performed well below average during assessment with a Success Score of 61%. During classroom activities the participant was highly detached and openly frustrated that she had to participate in the activity.

This could suggest that she was impacted by a significant level of self-as-source stereotype threat fueled by her perceptions about engineering and gender. Her standoffish attitude in class correlates with anxiety and displeasure which are associated with negative stereotype threats. This child did not exhibit signs of subgrouping or subtyping in an attempt to differentiate herself from her perceived negative stereotype. Further study is required to confirm this hypothesis. There was only one child who perceived herself to be part of a group with negative interest and ability in engineering topics, and therefore data was insufficient to validate this hypothesis. The child identified had a Total Difference score of $s = -14$ representing a very strong male-engineering bias. She performed well below average during assessment with a Success Score of 61%. During classroom activities the participant was very detached and openly frustrated that she had to participate in the activity. This could suggest that she was impacted by a significant level of self-as-source stereotype threat fueled by her perceptions about engineering and gender. Her standoffish attitude in class correlates with anxiety and displeasure which are associated with negative stereotype threats. This child did not exhibit signs of subgrouping or subtyping behaviors in an attempt to differentiate herself from the negatively stereotyped group. Further study is required to confirm this hypothesis.

## 8.4 Study II: Impacts of Robotics Performance on Gender-Based Engineering Stereotype Change

**Research Question of Study II** Do performance and happiness during the robotics unit predict change in these stereotypes?

### 8.4.1 Curriculum Implementation

The curriculum developed for this study was informed by data from studies with a previous version of the KIWI robots. As a result, some curricular concepts were presented too slowly, and others not in enough depth for use with the second prototype of KIWI.

In the first two lessons where the class learned the basiscs of CHERP, KIWI, and simple programming concepts, many students expressed frustration with the block scanning process. The scanner on the robots had difficulty reading the barcodes on some of the blocks. This error was not immediately addressable during class. It was difficult to explain to the children experiencing the error that a program was technically correct, just not scanned correctly into the robot. Many of the children vocally expressed that they did not like robotics, as they were associating the buggy prototype with all robots.

It is observed that these children were engaging in a negative stereotype grouping association highly similar to the subgrouping response discussed by Steele. These social dynamics were observed to assess whether the initial curriculum challenges would set a negative tone for the rest of the unit. The prototype blocks were modified to increase contrast of the barcodes on trouble blocks. As the robotics lessons continued, it was noted that the children were not permanently turned away from robotics because of hardware malfunctions during begining lessons. The children were taught how the robots were *suppsoed* to behave – i.e. they would beep once each time a block was scanned – and the children would ask a teacher for help or for a new robot if the robot was not functioning correctly.

Fortunately, the programming concepts presented in the first two lessons were easy to review in Program Your Teacher activities, and the children mastered them even though the scanning hardware was malfunctioning at times.

The next two lessons were presented as a series of exciting challenges and the class seemed reinvigorated at the idea of gamifying robotics tasks. The groups were organized such that students were partitioned by similar ability so that they could intellectually challenge each other to creatively solve the robotics tasks. As a byproduct of this method of grouping, some groups moved faster than others through the challenges. The groups that took more time to process and understand the beginning tasks often asked classmates in other more advanced groups for help explaining tasks before asking one of the adults in the classroom. The classroom environment became very collaborative and students were excited for each other when their robots successfully completed a challenge. Each time a robot scanned a new programmatic attempt to solve a challenge, many students would group around the testing area to watch the robot perform.

These lessons followed the pattern of the Engineering Design Process. For each challenge, every group would look at the paper, return to their table to build a robot and create a program, then go back to the paper to test their program. In most cases, the first program attempt would not accurately solve the problem. This forced the group to return to their building table to think more about the challenge and how they could modify their program or their robot to come up with a working solution.

This process was fun and exciting to the students. When one group was testing their program in front of a teacher that did not fully complete a challenge, the group excitedly scooped up their robot and discussed that they needed to modify their repeat blocks, then said to the teacher "Wait one second, we'll be right back!" and ran off to change their program.

Additionally, the paper challenge activities allowed students who were more apprehensive to feel comfortable making mistakes. Two of the female students who pre-tested with implicit and explicit male-engineering bias began the unit seemingly impacted by steretotype threat. Both girls were outgoing in other classroom activites, but were hesistant to get involved in group robotics work. During the paper challenges, all group members were faced with problems that were not immediately obvious to solve. As everyone made mistakes, the two girls became more comfortable also participating and contributing with less concern about being wrong.

Later in one of the more advanced challenges a group tested a program that did not work and seemed very stuck as to how to modify their program to solve the challenge. Instead of turning to the teacher that was observing the children, group members walked over to a group that had already completed the challenge to ask for help. Instead of giving the group that asked for help the answer, the advanced group helped explain the complicated distance sensor to the group asking for help. The first group was then able to apply what they learned from their classmates about how to use the distance sensor with repeats to solve the challenge. The collaboration observed in this, and many other instances during the curriculum is consistent with other studies about technology in early childhood classrooms [Wartella and Jennings, 2000; Education Development Center, 2013].

The structure of the paper challenges activity allowed for final projects to be tailored to groups based on their current level of understanding and programming ability. Four different final projects were assigned within the group. In class, the teacher had been teaching the students dances from different cultures. Each group was given a video of a dance from another culture and they were asked to program their robot to do the dance. Two groups square danced together, two groups performed "La Cucharacha" together, one group performed a line dance, and one group performed a dance "To the left, to the right, to the side, side, side" that they had learned in class. When the groups finished their projects, they taught the dance to the class and explained the programming concepts they used to create a dancing robot. Most groups used repeats, or sensors to perform synchronized dances.

As a part of the final project, each group presented their approach and experiences to the rest of the class. In the read-outs all groups impressed with how eloquently they could explain repeat concepts and programming challenges and successes to each other . The sensors were more complicated to understand, yet the groups that used them had a solid understanding of how they interacted with other other components of their robots.

Throughout the unit, it was observed that the kids enjoyed problem solving and the creative freedom that comes with robotics and programming. As one child said, “I love how many different ways you can make programs!”, and another peer chimed in, “I can make my robot do whatever I would like it to do!”. The excitement fostered a collaborative environment in the classroom where children were excited to share and teach each other about what they were creating.

Figure 8.3: Children building a KIWI Robot

### 8.4.2 Performance Assessment

**Hypothesis VI** Performance in robotics will not have a correlation to gender.

To test this hypothesis, the Solve-It challenges were used to assess each students performance in class. The Solve-It assessment was scored on a continuous scale. Each challenge offered 1 point for correctness, and 1 point for each computing element that it tested for. Total score was normalized to compare all tests to each other.

| Group | Average Score |
|---|---|
| Class | 81.7% |
| Girls | 83.0% |
| Boys | 80.0% |

Table 8.6: Solve-It Scores by Group

Figure 8.4: Children Scanning a KIWI Program built with CHERP blocks

Figure 8.5: Children explaining a CHERP program to each other

Variances of scores were determined for girls and boys separately with $\sigma_g^2 = 0.02, \sigma_b^2 = 0.03$. A two-sample t-test with equal variances was performed with t-value $t = 0.35$ concluding that as expected performance on robotics in the classroom was not correlated to gender.

**Hypothesis VII** Children who performed well on robotics assessments will group engineering-related careers to their gender

To test the seventh hypothesis a combination of quantitative tests and ethnographic observations were used. Quantitatively, the Solve-Its were used to assess performance in the classroom as described above. Following the scoring of Solve-Its, the children whose scores were above the class average were analyzed to how they grouped engineering careers during post-testing. In addition to the assessment of implicit gender bias derived from the grouping activity, each childs explicit perception of bias from post-testing scores for interest and ability were taken into account. Children were said to group engineering careers with their gender if more than half of the engineering images were placed into the gender pile that matched the gender of the child.

Nine children had scores above the class average of 81.7%. One boy and one girls data were not included in this analysis because they did not participate in the grouping activity during the post-testing phase. Four children – one girl, three boys – did not group images with their gender. Of these, two boys placed two images in each pile, and the other two children (one boy and one girl) each placed one image in the pile associated with their own gender and three images in the other pile. The perceived interest and ability scores for each of these four children were analyzed to see that interest and ability in engineering were determined to be gender-neutral properties to each of these children. The last child who did not group with her gender during post testing split the images equally into male and female piles, but had a slight bias in explicit perception towards boys having greater interest and ability in engineering topics than girls in her post-testing data.

The remaining two girls whose Solve-It scores were higher than average grouped engineering careers more with females than males demonstrating a higher level of implicit bias. One girl grouped 4-0 and one girl grouped 3-1. Analysis of the explicit interest and ability perception post-testing data for each of these girls demonstrated significant gender-bias suggesting males have a higher interest and ability in engineering than females.

This result supports the conclusion that these girls acknowledge explicit gender-based engineering stereotypes. Although they acknowledge explicit sterotypes, the grouping results from each of these girls reveal that stereotypes do not implicitly impact their perceptions. This result correlates with the presence of others-as-source stereotype threat. The high performance scores for both of these girls demonstrate their ability to overcome stereotype threat during the robotics curriculum and succeed at a high level.

**Hypothesis VIII** As a whole, there will be less difference in the implicit and explicit perception of boys' interest and ability in engineering topics as compared to girls' interest and ability in engineering topics after the robotics unit.

The final hypothesis was tested by looking at the standard deviation of explicit pre-testing data compared with explicit post-testing data. In the following tables the difference represents the score given by boys subtracted from the score given by girls.

Following the robotics unit in the classroom, we see from the above below that there was a very dramatic change in interest and ability perception across the board. In five of the six categories, the difference between the perceived ability of boys as compared to girls was markedly less in post-testing than in pre-testing. This data supports the hypothesis that introduction of robotics and engineering in the classroom can alter perception of gender-based engineering stereotypes.

Additionally, the Standard Deviations dramatically decreased across the board. This reflects an increase in agreement of the children in the classroom. Not only did the difference between boys and girls decrease for both explicit interest perception and explicit ability perception, but these opinions were expressed more consistently amongst children in the class.

| | Mean | Standard Deviation |
|---|---|---|
| Computer Programming | -0.7222 | 1.2274 |
| Robotics | -0.5 | 0.9235 |
| Engineering and Building | -0.5 | 1.0178 |
| Total | -0.5 | 1.0595 |

Table 8.7: Difference in the Class' perception of Girls' Explicit Ability from Post-Testing

| | Mean | Standard Deviation |
|---|---|---|
| Computer Programming | -0.05882 | 0.9824 |
| Robotics | -0.2647 | 1.03256 |
| Engineering and Building | -0.5294 | 1.1246 |
| Total | -0.2843 | 1.04525 |

Table 8.8: Difference in the Class' perception of Boys' Explicit Ability from Post-Testing

| | Mean | Standard Deviation |
|---|---|---|
| Computer Programming | -0.8 | 0.9411 |
| Robotics | -0.1333 | 1.1255 |
| Engineering and Building | -1.1333 | 0.8338 |
| Total | -0.6889 | 1.0406 |

Table 8.9: Difference in the Class' perception of Girls' Explicit Interest from Post-Testing

| | Mean | Standard Deviation |
|---|---|---|
| Computer Programming | -0.3056 | 0.8599 |
| Robotics | -0.2647 | 0.3611 |
| Engineering and Building | -0.25 | 0.6002 |
| Total | -0.3056 | 0.7360 |

Table 8.10: Difference in the Class' perception of Boys' Explicit Interest from Post-Testing

| | Average Decrease | Standard Deviation |
|---|---|---|
| Computer Programming | -91.85% | -19.96% |
| Robotics | -47.06% | 11.80% |
| Engineering and Building | -95.86% | -19.96% |
| Total | -91.85% | -19.96% |

Table 8.11: Class' Percentage Change in Ability Explicit Perception Post-Testing

| | Average Decrease | Standard Deviation |
|---|---|---|
| Computer Programming | -30.56% | -8.63% |
| Robotics | 70.83% | -32.18% |
| Engineering and Building | -77.94% | -28.01% |
| Total | -55.64% | -29.27% |

Table 8.12: Class' Percentage Change in Interest Explicit Perception Post-Testing

# Chapter 9

# Conclusions

After just six immersive classroom robotics, programming, and engineering lessons, the first and second grade students in this study demonstrated a decrease in awareness of gender-based engineering stereotypes.

Prior to the first lesson, most students acknowledged a standard gender-based engineering stereotype associating boys and men with greater interest in STEM stubjects, and a greater potential to succeed in engineering endeavors. The baseline assessments of perceived bias included both implicit and explicit measures of gender-based bias. Based on performance data following the robotics unit in class, data supported the hypothesis that children who perceived themselves to be part of a group with negaitve interest and ability in STEM subjects performed at a lower level in the classroom. This correlates with the anticipated adverse impacts of stereotype threat. These conclusions affirm the importance of addressing stereotypes in academic settings as the impact of stereotype threat, even at a young age, can be detrimental to the success of children in the classroom.

Although stereotype threat was present, the perceptions and impact of the negative stereotypes were dramatically reduced, and in some cases reversed. Girls who enjoyed and excelled at the robotics unit reported higher ability ratings for girls and women in both their implicit and explicit stereotype post-assessments. The same behavior was seen in the data from boys, although the difference between the perceived interest and ablity of boys to the interest and ability of girls was much narrower than it was during the pre-testing.

Finally, cognitive assessments reported a deep level of understanding of most robotics, engineering, and computer programming concepts taught during the unit. The overall cognitive scores confirm that advanced programming concepts such as repeats, sensors, and conditionals are well within the intellectual potential of first and second grade students.

The success of both the curriculum and stereotype reduction reflect positively on continuation of study.

# Chapter 10

# Suggestions for Further Study

This pilot study succeded in predicting gender-based engineering stereotype reduction in first and second graders after an open and collaborative robotics unit in the classroom. This research could natrually develop into an analysis of the acknowledgement of gender-based engineering stereotypes in children as they progress through elementary school. As children get older, their social awareness develops and social pressure may have a more direct impact on academics. Additionally, the impacts of social pressure on academic performance in STEM topics, and acknowledged gender-based engineering stereotypes at each grade level could be condsidered as additional factors contributing to variance in stereotype awareness.

This study addressed students in the first and second grades. A study over a variety of grade levels exploring the effects of whether introducing robotics and engineering into the classroom had similar stereotype-reduction effects at older ages is a natural progression of research. The multi-grade study could include a comparison the difference in social impact on stereotypes and performance for those students who have had previous curricular robotics and engineering experience, to those who have not yet been exposed to these topics.

In future studies, I would like to differentiate STEM subjects. In this study, stereotypes were analyzed grouping together data about robotics, engineering and building, and computer science. I am interested to see whether gender-based engineering stereotypes are present for all STEM subjects separately. If so, I would like to study whether stereotypes are stronger in subjects which students have had in-classroom exposure – such as mathematics and basic science – or if stereotypes are consistent across the board.

Further areas of inquiry may consider the impact of the gender of the educators, including the researcher(s), on stereotype reduction outcomes. In addition to educator gender, it has been observed that the classroom environment by itself can amplify percieved stereotypes and impact interest levels in children. (Brogrammer) A study that incorporates educator gender, could also measure the effects of stereotype threat amplification by advising gender groups in advance of activities that one gender tends to perform "better" or "worse" than the other. A control group could be advise that gender groups tend to perform at the same level, or not performance indications could be given.

Continuation of this study could inform educators, administrators, and parents about the importance of including robotics and engineering topics in the classroom; and the academic impacts of stereotypes on a child's interest and performance in STEM curricular areas.

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