FACT: Femineer® Active Learning with Computational Thinking

Dr. Kristina Rigden, California State Polytechnic University, Pomona

Dr. Rigden is the Director of Outreach Programs and the Women in Engineering Program for the College of Engineering at Cal Poly Pomona. In her position, she secures funding and provides several different outreach programming events to engage K-12 female students to pursue STEM majors and/or careers. Dr. Rigden’s research focus is the STEM pipeline from K-12 to college and career for underrepresented minorities. Her teaching and scholarship are grounded in the conceptual framework of culturally responsive pedagogy and andragogy for teaching diverse populations of students in virtual learning environments. Dr. Rigden earned her Doctor of Education in Educational Leadership with a concentration in Teacher Education in Multicultural Societies from the University of Southern California.
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Abstract

The Cal Poly Pomona College of Engineering Femineer® Program is a unique and innovative program devoted to inspiring and empowering K-12 female students to pursue STEM majors and careers. Created in 2013, the program enhances the College of Engineering’s commitment to support underserved populations by recruiting and graduating increased numbers of historically underrepresented students. This mixed method study determined what factors are involved in identifying STEM-confidence in a female-only classroom environment in a middle school, and if students developed algorithmic reasoning or computational thinking interacting with the new Innovative Coding curriculum. The results from this study showed that Femineer® students regulated their own learning by working together and individually to construct and program the Ardibot. This was achievable since the instructor and teachers provided clear instruction to the students about the Innovative Coding curriculum.

Overview of the Study

STEM jobs are increasing and the US workforce will need more STEM workers in the future [1], [2]. “STEM occupations include computer scientists and mathematicians; engineers and architects; life, physical, and social scientists; medical professionals; and managers of STEM activities” [3]. According to ISACA, the United States will need 1.4 million workers in computer-related fields in 2020 and the U.S. will only be able to fill 29% of those jobs [4]. With the increase of STEM workers, research has shown that men outnumber women in the STEM field. According to the National Center for Education Statistics, 36% of STEM bachelor degrees were conferred to women in 2016 [5]. Within the STEM field, 19.8% of engineering bachelor degrees [6] and 18.1% of computer science bachelor degrees were conferred to women in 2014 [7]. This data shows that women are earning less engineering and computer science bachelor degrees and there has not been much progress since 2004. These percentages are very low, and need to be increased for females to compete in this global economy.

Despite all the odds, women were at the forefront of technology in history. Ada Lovelace (1815-1852), the only daughter of poet Lord Byron had an interest in literature and mathematics. She collaborated with Charles Babbage on his Analytical Engine and she is considered the first computer programmer in history [8]. One hundred years later, Grace Hopper (1906-1992) led the development of the first programming language compiler, which led to the popular COBOL language [9]. Although women were at the forefront of software development, today a low number of female students are interested in learning to program and choosing a career in technology [10], [11], [12]. Studies indicate that a large number of qualified female students lose interest in engineering and technology as early as middle school [13], [14].

Programming is fast becoming the most critical job skill of the future. Unfortunately, when it comes to programming, men vastly outnumber women. In the technology industry, women constitute 14-18% of technology workers [15]. However, programming skills are only part of overall development. While it is important to know how to program in a specific language, what is even more important is to develop computational thinking skills that can help to program in any
language. Steve Jobs once said, “I think everybody in this country should learn how to program a computer, to learn a computer language, because it teaches you how to think…I view computer science as a liberal art” [16]. Knowing how to program can help students learn how to lay out a plan, evaluate the methodology, troubleshoot problems, and implement a strategy.

Background

Many initiatives in the 21st century focus on teaching programming skills, such as C and Python to students. Teaching programming languages follows a pattern: start with syntax; demonstrate or model to students how to create simple programs using basic arithmetic operations; print statements to the screen; and then introduce students to loops and conditions. While some students strive in this approach, most students struggle and never master programming skills [17]. In fact, many students are not engaged in programming as it lacks context and practical applications. In addition, programming languages themselves become outdated and change over time. Just 25 years ago, FORTAN seemed like the language of choice for STEM, until C took over. Languages such as COBOL, Pascal, ADA, and LISP are no longer utilized. While it is important to know how to program in a specific language, what is even more important is to develop computational thinking skills that can help students program in any language.

This paper illustrates the creation and implementation of an innovative approach to develop algorithmic reasoning and computational thinking with two popular programming languages, C and Python for middle school female students by using a hands-on, application-oriented approach. The research questions for this study are:

1) What factors are involved in identifying STEM-confidence in middle-school female students when learning in a female-only STEM learning environment?

2) How are Femineer® students developing algorithmic reasoning or computational thinking through participation in this Innovative Coding curriculum?

This curriculum will become part of the Femineer® Program, which is currently a three-year curriculum program for middle school and high school female students with a focus on programming, robotics, technical skills, critical thinking, and creative inspiration.

Femineer® Program

The Femineer® Program was developed by the College of Engineering at California State Polytechnic University, Pomona (Cal Poly Pomona) to increase the number of women in STEM majors and careers. Created in 2013, the Femineer® Program enhances the College of Engineering’s commitment to support underserved populations by recruiting and graduating increased numbers of historically underrepresented students. The Femineer® Program started with one cohort in the 2013-2014 school year with 24 female students (freshman and sophomores) from Fremont Academy of Engineering and Design in the Pomona Unified School District. These participants completed two years in the program during which they engaged in projects featuring Creative Robotics and Wearable Technology. The 2015-2016 academic year marked the third and final year of this first cohort’s participation and saw the expansion of the Femineer® Program to nine schools with more than 200 students. The expansion continued in the 2016-2017 school year
with 14 additional schools, with more than 400 students. In addition, the University of Iowa and San Diego State University signed on as affiliate universities ready to help start and expand the Femineer® Program in their areas. In the 2017-2018 school year an additional 20 schools joined, bringing an additional 450 students. The 2018-2019 school year had 43 new schools join the Femineer® Program and the 2019-2020 school year welcomed 29 new schools.

A quantitative pilot evaluation of the Femineer® Program was conducted in the summer of 2017 with 173 participants at eight schools. All participants in the pilot study were female and they reported their race/ethnicity as predominantly Hispanic/Latina (77%), with lower numbers of participants describing themselves as Asian/Pacific Islander (11%) or White/Caucasian (9%). A small number of participants described their race/ethnicity as “other” or did not report (3%). The results of this pilot evaluation was presented as a paper (Femineer: An Innovative and Engaging Program to Empower K-12 Female Students) at The Collaborative Network for Engineering and Computing Diversity (CoNECD) conference in 2019.

The Femineer® Program targets the recruitment of new schools in the local areas of University affiliates and by presenting at educator conferences. Many of the attendees at educator conferences work at Title I schools (schools with large concentrations of low-income students that receive supplemental funds to assist in meeting student’s educational goals), which have large student populations of underrepresented minority students. Of the 87 participating schools in the 2018-2019 school year, 59 Femineer® schools are classified as Title I.

The Femineer® Program is currently a three-year hands-on curriculum 1) Creative Robotics, 2) Wearable Technology, and 3) Pi Robotics. Each year is comprised of a 30 to 40-hour project. Creative Robotics focuses on Scratch programming by using the Hummingbird control platform. The robot structure is open-source and includes a controller board, sensors, motors, and real wiring. The new curriculum, Innovative Coding, will expectantly become the second year of the Femineer® Program, after Creative Robotics and before Wearable Technology. Therefore, the Femineer® Program will become a total of four years of curriculum. Having the foundational knowledge of engineering and computational thinking in year two will help the students when they move onto year three of the curriculum. Wearable Technology concentrates on C programming with an Arduino chip control platform, sewing with conductive thread, and soldering. The focus of Pi Robotics is on Raspberry Pi by using the Python programming language to build a robot and give tasks to the robot to perform. The skills that the Femineer® students are learning in the current three-year program entail skills that engineering students are exposed to in college; however, the Femineer® students are able to learn the curriculum through hands-on experience and become confident in these skills before entering college.

In addition to the students learning programming and engineering skills, students are exposed to problem-solving, team-building, and engineering mentors. Several Femineer® schools have local engineering guest speakers come to the Femineer® classroom to speak about their profession, and other schools take field trips to local industry sites. Schools close to the University Affiliates attend the yearly Femineer® Summit to showcase their final projects. Each Summit hosts a keynote speaker from industry, students participate in break-out sessions, and mingle with female engineering students at the local university. At the Summit, Femineer® students meet each other
and see their final projects in the yearly showcase. This networking opportunity for students exposes them to being on a college campus and meeting fellow Femineer® students and engineering students.

The importance of the Femineer® Program becoming four years of curriculum is the opportunity for middle school students to start the program when they are in sixth or seventh grade with the opportunity to continue with the Femineer® Program when they reach high school. It is recommended for the Femineer® students to all start with the first year of Creative Robotics and move on sequentially to the following years so students have the content knowledge needed to continue with the following years of the program. This opportunity for growth and development of STEM learning will continue in the high school grade levels. The Femineer® students learn how to work in a collaborative environment, have opportunities for creative expression, technology integration, and an inquiry-based approach to learning. All of these skills are also implemented in the College of Engineering’s undergraduate and graduate degree programs as the college prides itself in a learn-by-doing philosophy.

The curriculum of the Femineer® Program is hands-on and collaborative. All students in the program receive an engineering notebook, which has lined and graph paper so the students can write-down and sketch their ideas. There is no traditional notebook with activities that students have to finish for a grade. The teacher is the facilitator of the curriculum and communicates to the students how to accomplish the engineering tasks. Because of the constructivism approach, students are engaged in their own learning. All students work in small groups in the Femineer® Program so non-native English speakers are able to participate in the curriculum at their own pace and with the help of their classmates. This flexibility of the constructivist curriculum allows all students to participate regardless of their English or engineering ability.

The Femineer® Program was named a recipient of INSIGHT Into Diversity magazine’s 2019 Inspiring Programs in STEM Award. This award was presented as a tribute to programs that encourage and inspire a new generation of young people to consider careers in science, technology, engineering, and math. The White House Initiative on Educational Excellence recognized the Femineer® Program in 2016 for increasing educational outcomes and opportunities for female Hispanic K-12 students across the country. The program was commended for its focus and goals that include mentoring opportunities for Hispanic K-12 students in STEM subjects, and investing in support for teachers through professional development workshops.

**Literature Review**

This FACT (Femineer® Active learning with Computational Thinking) study utilizes two research questions 1) What factors are involved in identifying STEM-confidence in middle-school female students when learning in a female-only STEM learning environment? and 2) How are Femineer® students developing algorithmic reasoning or computational thinking through participation in this Innovative Coding curriculum? The research questions are grounded in Albert Bandura’s social cognitive theory. The researcher will use the first question to answer and identify the factors involved in STEM-confidence in middle-school female students when learning in a female-only STEM learning environment. *(It is important to note that many Femineer® schools*
operate the program as an after-school club or a Saturday club so the female students can all gather on their own time; male students are not excluded from the Femineer® Program). Social cognitive theory will be used as the framework to define STEM-confidence and learning in a single-gender educational environment. The researcher will use the second question to identify how Femineer® students develop algorithmic reasoning or computational thinking through participation in this Innovative Coding curriculum.

**STEM Confidence**

Albert Bandura’s self-efficacy theory is developed in the field of behavioral change and he states that “…cognitive processes mediate change but that cognitive events are induced and altered most readily by experience of mastery arising from effective performance” [18]. The mastery that arises from this effective performance is defined as confidence. Confidence is the self-belief in people’s competence or chance to successfully complete a task [19]. Perceived self-efficacy in students is defined as the students’ beliefs in themselves to regulate their own learning, level of motivation, and master academic activities, which lead to academic accomplishments [20]. Self-efficacy theory is used in this study to help students develop STEM-confidence.

Student views of teachers can inform student success [21], [22]. For faculty that interact with students and provide them with opportunities, these students have higher levels of self-efficacy [23]. In addition, women believe verbal persuasions from their teachers are highly influential in their confidence [24].

Students who observe their peers performing a task successfully believe they can also accomplish the task [25], [26]. In Litzler, Samuelson and Lorah’s study [23], comparison to peers was a survey question in their study (“Compared to other students in my classes, I think my academic abilities in my engineering classes are: far below average = 1; below average = 2; average = 3; above average = 4; far above average = 5”) about STEM confidence and it was ranked 3.57 out of a scale of 5. In Sankar, Gilmartin and Sobel’s study [27], class size impacted overall confidence levels. In mixed-gender STEM class sizes of under 30 people, women answered 23% fewer questions. Women answered 26% fewer questions in class sizes 31-70 people, they answered 31% fewer questions in class sizes 71-100 people, 42% fewer questions were asked in class sizes 101-500 people, and 50% asked fewer questions in class sizes of over 500 people.

In the STEM field, students that perceive it as rewarding field serve as a source for self-efficacy beliefs [23]. When students believe that engineering work will satisfy their interests and values, they remain persistent to finish their degree [28]. From the prior research conducted on STEM-confidence [29], [23], [27], [24], the variables of STEM-confidence are student views of teachers, comparison to peers among class size, and perceptions of the field as rewarding. These three variables will be used to answer the research question and align with social cognitive theory. There are many studies on learning in a single-gender environment. Smyth’s [30] article summarized the research findings from different studies on single-gender schooling in the English-speaking countries of Australia, Great Britain, Ireland, New Zealand, and the United States of America. Smyth found that female students perform better in mathematics and science class when in a female-only classroom. Anafara and Mertens’s [31] article on single-gender classes found that
female students in a single-gender school perceive math and science as less masculine and therefore, have a stronger preference for those classes. The findings also noted that a single-gender school can lead to higher student self-esteem for both genders. Barton and Cohen [32] advocated that female students benefit academically from gender segregation in the classroom. While there are critics on both sides of single-gender or mixed-gender classrooms, it is important to note that several studies have cited how female students perform better in STEM subjects when in a single-gender smaller-size classroom.

Figure 1. Conceptual framework of research question 1

These studies build on the framework of Bandura’s social cognitive theory [18], which is defined as new patterns of behavior acquired through direct experience or by observing the behavior of others. Learning through observing the behavior of others, or modeling, involves four interrelated sub processes: 1) attentional process in which a person will not learn if they do not recognize the importance of the skill; 2) retention process wherein a person cannot be influenced by observation if he/she has no memory of the event; 3) motoric reproduction process where a person must have the necessary skills to produce new patterns of behavior; 4) reinforcement and motivational process in which a person can acquire, retain and possess capabilities of a skill, only if the learning was positively received [18]. These sub processes of social cognitive theory will be used to answer the research question about learning in a single-gender environment.

Computational Thinking

Algorithmic reasoning is a way of thinking to get to the solution by using instructions or rules that are followed precisely [33]. According to Jeannette M. Wing [34], a computer science researcher, computational thinking is a fundamental skill for everyone that involves problem solving, designing systems, and understanding human behavior by drawing on the concepts fundamental to computer science by thinking at multiple levels of abstraction. There are four categories of computational thinking: data practices, modeling and simulation practices, computational problem solving practices, and systems thinking practices [35].

Data practices involve the collecting, creating, manipulating, analyzing and visualizing data. Modeling and simulation practices comprise using computational models to understand a concept and find and test a solution, and assess, design and construct computational models. Computational problem solving practices include preparing problems for computational solutions,
programming, choosing effective computational tools, assessing different approaches/solutions to a problem, developing modular computational solutions, creating computational abstractions, and troubleshooting and debugging. Systems thinking practices entail investigating a complex system as a whole, understanding the relationships within a system, thinking in levels, communicating information about a system, and defining systems and managing complexity [35]. Since computational thinking has now been defined, it is important to look at K-12 computational thinking and how students can develop this skill.

Figure 2. Conceptual framework of research question 2

Grover and Pea’s [36] review of the state of computational thinking in K-12 education state that there is still not a lot of research on K-12 teaching and learning programming and computer science. However, using Makerspaces or “computational craft” kits allow younger students to combine arts and crafts with computation and electronics. This allows younger students to learn computational thinking in a variety of environments. Orton, Weintrop, Beheshti, Horn, Jona and Wilensky’s [37] study on bringing computational thinking into high school mathematics and science classes resulted in an increase in female student’s confidence in STEM. This is important because it shows how computational thinking can influence STEM-confidence in female students.

Computational thinking is seen as a core scientific practice since it is included in the NGSS. It is important for students to develop this skill. In order to answer the second research question presented in this study, the four categories of computational thinking and “computational craft” kits are utilized to identify if students are developing computational thinking skills.

**Research Design Methods**

The researcher used mixed method methodology, which enabled comprehensive data to be collected. Mixed method methodology is a combination of qualitative and quantitative research that guides the philosophy and research design [38]. This study utilized observations, interviews, focus groups, document collection, and a survey.

For this mixed method research study, several pieces of data were collected. First, observations occurred in the classroom conducted by the researcher. Next, an audio-recorded interview took place with the two Femineer® teachers from the middle school and the Femineer® instructor who facilitated this pilot curriculum. Audio-recorded focus groups took place with the Femineer® students. The interview and focus groups helped gather the teachers and students
thoughts and opinions of the Innovative Coding curriculum, which cannot be directly observed in a classroom setting [39]. In addition, a survey was distributed to Femineer® students. Lastly, document collection of the student classwork samples from the Innovative Coding curriculum took place.

Sample

The participants were found by purposeful sampling. Purposeful sampling enabled the researcher to connect with participants that provided particular information that was relevant to answering the research questions [40]. The setting for this study was a classroom at a 4th – 8th grade public middle school in San Diego County.

Participants

The participants for this study were the two Femineer® middle-school teachers, the Femineer® instructor and Femineer® students who had completed year one curriculum of Creative Robotics. The two Femineer® female teachers from the middle school have experience with year one of the Femineer® curriculum, Creative Robotics. The Femineer® teachers teach in the STEM field at their middle school. The Femineer® teachers were chosen for this study from the local host university since they have experience with year one curriculum of the Femineer® Program. The Femineer® Instructor is a male mechanical engineering professor at the local host university who is co-founder of the Femineer® Program and developed all three years of curriculum for the Femineer® Program, including Innovative Coding. He worked with the two Femineer® teachers from the middle school to teach this pilot curriculum to the female students.

Twenty-one Femineer® middle school students also took part in this study. The Femineer® teachers at the middle school recruited 21 Femineer® students to participate in this study. The criteria for the Femineer® students were that they needed to be enrolled students at this middle school and actively participate in the Femineer® Program. Once the Femineer® teachers identified 21 students to participate in this study, the student’s parents signed all of the required documentation to participate in the study according to the Institutional Review Board (IRB) research protocol. The demographics of the participants are 19% Asian American or Pacific Islander, 14% Black or African American, 57% Hispanic or Latino, and 10% White.

Data Collection and Instruments/Protocol

This research study is comprised of observations, interviews, focus groups, a survey, and document collection to answer the research question. Multiple methods of data collection were utilized.

Observations

Observations were used during the study to help answer the research questions. The researcher conducted three one-hour long observations in the classroom when the Femineer® students were working on their Innovative Coding projects. Observations gave the researcher a firsthand account of the actions that took place during the class. The observations took place after
the survey and before the interview, focus groups, and document collection. The researcher observed the participants and made notes on the female-only learning environment, algorithmic reasoning and computational thinking, and active learning with the Innovative Coding curriculum. The researcher has been trained in qualitative research methods, which focus on using observations to triangulate the data.

**Interview**

One audio-recorded and transcribed interview took place with the two Femineer® middle-school teachers and the Femineer® instructor. The interview was conducted face-to-face and lasted 25 minutes. The researcher also took notes during the interview. After the interview, the researcher transcribed the audio-recorded interview. The interview took place after the observations. The interview protocol addressed the different types of interview questions to stimulate responses from the Femineer® teachers and instructor [39]. The interview questions ranged from an experience question to a knowledge question, and a feeling question [39].

**Focus Groups**

Audio-recorded and transcribed focus groups took place with the Femineer® students. The focus groups were conducted face-to-face and lasted 20 minutes. There were 21 Femineer® students that participated in the focus groups. Notes were taken during the focus group and transcribed. The focus group took place after the survey and observations. The focus group protocol addressed the different types of focus group questions to stimulate responses from the Femineer® students [39]. The interview questions ranged from a knowledge question to an opinion question, and an experience question [39].

**Survey**

One survey was given to the Femineer® students the morning before their interaction with the Innovative Coding curriculum. Twenty-one Femineer® students took the survey. The survey was given to the students on paper and it took ten minutes to complete. This likert scale survey was created by the researcher and can be found in Appendix A. Construct validity was used to measure the Femineer® students thinking and engineering skills in line with the Femineer® Program, which relates to the conceptual framework and research questions for this study [41].

**Document Collection**

Submission of documents consisted of student classwork samples from the Innovative Coding pilot curriculum. The student samples were collected from the Femineer® teachers. Although there was no protocol for document collection and analysis, elements of STEM-confidence, algorithmic reasoning and computational thinking, and active learning were analyzed and used as triangulation to support the participants in the study.

**Logic Model**

Figure 3. Logic model of the Femineer® study
Data Analysis

The data was analyzed using mixed methods to identify factors of STEM-Confidence and development of algorithmic reasoning or computational thinking through active learning with the Innovative Coding curriculum. The results of the survey were transformed from numeric codes to narrative data so the results were analyzed concurrently with the qualitative data. Quantitative data converted into narrative data (qualitizing) is a unique characteristic of mixed method design and data analysis [42].

The survey data; interview transcript with the Femineer® teachers and instructor; focus group transcript with the Femineer® students; observation notes; and student classwork was printed out so they were coded. All of the words or phrases about STEM-Confidence, algorithmic reasoning, computational thinking, or active learning was typed into an excel document with a definition and a page number to refer to the raw data. These words or phrases became the 85 open codes. After color-coding the open codes that were similar, this resulted in 13 axial codes of categories. Similar axial codes were combined which resulted in three selective codes. The researcher used the selective codes to help answer the questions.

Credibility and Trustworthiness
Triangulation helped with credibility through the interview and focus group transcripts, observations, and documents. The researcher conducted verbal member checks with the students in the late afternoon on the last day of the pilot and written member checks with the Femineer® teachers and instructor two weeks after the pilot. Member checks enable feedback from the participants in the study to gain their insight to see if the researcher captured all of the data accurately [40].

Ethics

The IRB (IRB-18-139) approved this study as full board review. All participants in the study were given an informed consent form that addressed the details of the study. The consent forms were provided in English and Spanish to the Femineer® students’ parents since the students were under the age of 18. The researcher explained the purpose of the study to all participants and set up additional time to meet with participant’s parents in case they had any questions or concerns about the study. The researcher promised all participants that their interview responses and focus group responses would remain confidential. The responses were coded under a pseudonym and kept on a password-protected computer in the researcher’s office.

Findings

The purpose of the study was to identify factors of STEM-confidence in a female-only learning environment. The study also analyzed how Femineer® students developed algorithmic reasoning or computational thinking through participation in the new Innovative Coding curriculum. This mixed method study had the following participants: two Femineer® teachers, one Femineer® instructor and 21 Femineer® students. The basis of analysis was developed from the literature of Albert Bandura’s self-efficacy theory [18], [20] and computational thinking [35], [36]. Three one-hour in-person observations, three in-person audio-recorded interviews with the Femineer® teachers and instructor, and three in-person audio-recorded focus groups with the Femineer® students occurred. Surveys were collected from 21 students. The researcher engaged in document collection consisting of student classwork from the Innovative Coding curriculum. The data collected from this study addressed the following research questions: 1) What factors are involved in identifying STEM-confidence in middle-school female students when learning in a female-only STEM learning environment? and 2) How are Femineer® students developing algorithmic reasoning or computational thinking through participation in this Innovative Coding curriculum?

In this findings analysis, the researcher addressed if the Innovative Coding curriculum approached factors of STEM-confidence while learning in a female-only classroom environment, and how Femineer® students developed algorithmic reasoning or computational thinking through participation in the new Innovative Coding curriculum. The findings will be addressed by using the three selective codes from the codebook analysis described in the data analysis section: 1) clear instructions from the instructor and the teacher; 2) students working together and individually; and 3) programming. First, the two selective codes of clear instructions from the instructor and the teachers, and students working together and individually will be discussed as two factors in identifying STEM-confidence in middle-school female students. Second, the last selective code of programming will be addressed as to how Femineer® students develop algorithmic reasoning or
computational thinking through participation in this curriculum.

1. Clear Instructions from the Instructor and the Teachers

Before the class began to learn about programming and constructing the Ardibot (bot), the teachers gave the instructor a USB drive and asked for the PowerPoint and the bot assembly instructions to be put on the USB drive. Once this was completed, the teachers passed around the USB drive and had all students load the PowerPoint and the bot assembly instructions on their computer. Each student in this class had their own computer. Once the students had the learning material at their disposal, they were able to regulate their own learning and start assembling their bot [20]. In order to properly assemble the bot, many students learned the names of the tools to assemble the bot, such as: screwdriver, nut, bolt, screw, casters. This was helpful so the students could ask the instructor and teachers for help with the assembly. For example, one student asked the teacher to hold the bot for her so she could screw in the screws to the casters on the bot. Acquiring and retaining the name of the tools and supplies to assemble the bot is important for self-efficacy [18].

The instructor was clear with directions to the students about the task. For example, the instructor stated, “I want to introduce you to a buzzer. Can you find it in your kit?” The instructor then held up a buzzer in his hand and the students looked for their buzzer. The instructor then said, “The buzzer has two legs. Are they the same?” One student said no and the instructor said, “What does that mean?” The same student said positive and negative so then the instructor told students to put their buzzer legs into the breadboard. Showing the process behind what the students are supposed to be doing helps them learn by acquiring knowledge through direct experience with the object, in this case, the buzzer and the breadboard [18].

Throughout the assembly of the bot, one student remarked that she was nervous because she felt like she was going to mess up a lot. However, once this student had a fully assembled bot, she was confident in her engineering skills [19]. This is important because only 52% of students agree or strongly agree that they are confident in their engineering skills, yet 85% of students agree or strongly agree that they are confident in the Femineer® Program.

2. Students Working Together and Individually

During the pilot of this curriculum, there was evidence of pair work and individual work
among the students. During bot assembly and programming, only two sets of pairs worked together to help each other construct their bot and check their programming. For instance, one student asked the student sitting next to her for help and the student said that she was busy. The student then replied and said, “what if you need help and nobody will help you” and the student then agreed to help. With only two sets of pairs working together during this pilot, the remaining 80% of students worked individually. It was interesting to observe that whenever a student had a question, she raised her hand to ask the instructor or teachers for help, not a student that was sitting next to her.

With the majority of students working individually, they had very specific comments and responses to the questions in the focus group. One student remarked that she is proud of herself for making the robot move since she did it all herself. Another student said she built the robot without the help of anybody else and saw her own creation come to life. Additionally, a student said, “I learned a lot by doing things by myself.” In these examples, the students demonstrated perceived self-efficacy since they believed in themselves to regulate their own learning [20].

**Gender**

Students had varying thoughts on being in a mixed-gender classroom versus a female-only classroom. Thirty-eight percent of students agree or strongly agree and 42% of students neither agree nor disagree that they like being in a female-only classroom. In the focus group, one student commented that she prefers a female-only classroom because “…boys try to rub it in our face that they think they are smarter.” Another student echoed this and said she feels more confident and comfortable in an all-girls class because boys like to move around a lot and not get things done.

In the focus group, a student resonated that she can be herself around all the girls and she will not be made fun of if she does the wrong thing. Additionally, one student said, "I felt like it was really good to have an all-girls class because usually boys are always teasing and are never serious, but with all the girls, things actually got done." These students preferred being in a female-only classroom environment for the Femineer® Program which had a focus on math and science [31].

In another focus group, the consensus seemed to be on the preference of a mixed-gender classroom. One student mentioned, "I think it's cool to have an all-girl class, but boys should have a chance to be in a [Femineer®] program like this." Another student reiterated, "Boys have different mindsets than girls and they can also help us out and we can help them out as well." A third student confirmed, “An all-girl environment gives us the chance to be comfortable around each other, but I also think we would try to be with guys to be in an equal environment.” Lastly, a quote from the focus group, “I feel a bit more comfortable [in a mixed-gender classroom] but my comfortableness depends on if there's people I know well around me and most of my friends are guys, but I do have many friends that are girls who I feel comfortable around." This last statement conceptualized the study with learning in a female-only environment because this particular student was part of the Femineer® Program, but did not know many of the female students in the program; therefore, she did not feel comfortable in her learning environment with people she did not know. In this situation, it is important to look at the student’s academic progress in the pilot curriculum to see if the student is benefitting academically [32].
3. Programming

The Innovative Coding curriculum uses the Ardibot and C programming language. Programming was new to the students and they said they “learned how to do something that we do not do in other classes.” One student mentioned, "I've done something similar in my computer engineering class with programming, and this was a little bit more challenging." Based on the survey that was given to students, 57% of participants agree or strongly agree and 33% neither agree nor disagree they can program.

Figure 4. Making the Ardibot move forward

```c
//Stage 3:
//Ardibot moves forward until it detects a wall (same as Step 1)

while(stage3 == 0)
{
    ping();
    distance = cm;
    //print
    Serial.print(inches);
    Serial.print(" in.");
    Serial.print(cm);
    Serial.print(" cm");
    Serial.println();
    delay(10);
    if (distance > MaxDistance)
    {
        //Ardibot goes forward
        GoForward(speed7, speed8);
    }
    else
    {
        //Ardibot stops
        StopMotor1();
        stage3 = 1;
    }
}

//Stage 4:
//Ardibot turns right (270 degrees CW)
//During this step, the Ardibot will pick up the washer as it is moving 270 degrees CW

while(stage4 == 0)
{
    TurnRight90(95);  //1st time to the right, back, and forth
    delay(500);
    Reverse(95, 85);
    delay(2300);
    GoForward(95, 85);
    delay(2000);
    TurnRight90(95);  //2nd time to the right, back, and forth
    delay(500);
    Reverse(95, 85);
    delay(2300);
    GoForward(95, 85);
    delay(2000);
    ```
In the afternoon on the second day of instruction, the Femineer® instructor asked students to program the bot to go straight. When students used their knowledge of programming to model and simulate the bot into moving straight, they utilized computational thinking and problem solving when their bot would move in circles instead of going straight [35]. This led to an assessment of different approaches and solutions to the problem of the bot not moving in a straight line. One student said, “the biggest challenge I faced was making sure the program was correct” when I was trying to get the bot to move in a straight line. From this trial and error of trying to make the bot move straight, students were able to evaluate the problem and find a solution. From the survey that was given to students, 80% of participants agree or strongly agree and 20% neither agree nor disagree that they can evaluate information, and 90% of participants agree or strongly agree and 10% neither agree nor disagree that they can understand a problem and find a solution.

Limitations and Delimitations

Limitations influence me as a researcher, and a limitation in this study is that I have personal connections to the Femineer® Program as the Director of the program at one university host site. Delimitations are choices that I made as a researcher that may affect my data. A delimitation is that with a mixed method study there may be some skewing of the qualitative data. As the researcher, I am the primary data collector and analysis instrument, and this may affect the findings. I also studied one Femineer® school site with a small population of 21 Femineer® students, one Femineer® instructor and two Femineer® teachers.

Summary of Findings

The three codes of clear instructions from the instructor and the teacher, students working together and individually, and programming enabled students to develop STEM-confidence and learn algorithmic reasoning or computational thinking. The students were able to learn the names of all the materials and tools that they were using, and enabled them regulate their own learning.
which was an element of STEM-confidence. In addition, once students were able to complete a task of bot assembly or correct programming individually or working together, they felt confident in their engineering skills. Having accessible assembly directions for the students was very helpful so students could work at their own pace to build the bot. When students were tasked with making their robot drive in a straight line, they felt they were tasked with a big challenge. By utilizing algorithmic reasoning or computational thinking with problem solving, they were able to find a solution.

Implications for Practice

Clear instruction from the instructor and/or teachers can inform future teaching of algorithmic reasoning or computational thinking. The instructor and/or teachers should be familiar with programming and assembly of the bot. The process of troubleshooting should be taught to the students so they learn how to troubleshoot on their own when their program is not working. The troubleshooting process is also important to reiterate to students so they ask each other for help before they ask the instructor or teacher. In regards to programming and the curriculum, students need to be taught the skills of how to program and then given programming tasks to complete. This was an effective learning method for students, but not all students had fundamental programming skills before progressing to more advance programming.

Recommendations for Future Research

More research would need to be conducted on the impact of the gender of the Femineer® instructor or teacher. In this study, the Femineer® instructor was male, the two middle-school teachers were female and all the students were female. It would be interesting to see the dynamic of a female Femineer® instructor in a classroom with all female students. In addition, the students seemed to prefer a mixed-gender classroom to a female-only classroom from the survey results and the focus groups. These students were in middle school, so it would be interesting to see if the results varied depending on a high school classroom. Moreover, it may be possible that individual interviews with students will yield different results of the gender-based question based upon group consensus in a focus group.

Conclusion

This study examined factors of STEM-confidence in a female-only learning environment and how students develop algorithmic reasoning or computational thinking through the Innovative Coding curriculum. The outcomes of this study resulted in students regulating their own learning by working together and individually to construct and program the bot. This was achievable since the instructor and teachers provided clear instruction to the students about the Innovative Coding curriculum. From this study, the suggestions are for teachers to be familiar with programming and assembly of the bot, and teaching students the process of troubleshooting. Recommendations for further study include the gender of the Femineer® instructor or teacher and conducting the study in a high school environment to see if the mixed-gender versus female-only classroom environment changes perceptions of the Femineer® Program.

Acknowledgements
This work was supported by a 2018 grant from the Motorola Solutions Foundation.
References


## Appendix A

**Femineer® Survey**

We would like to get some feedback from you about the Femineer® Program. There are no right or wrong answers to these questions; we just want your opinions. All your responses will be kept confidential. For each statement, please circle the number that best matches your answer.

<table>
<thead>
<tr>
<th>Femineer® Program</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like making things.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I like “arts and crafts.”</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I like being in a female-only classroom.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I enjoy the Femineer® Program.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I feel confident in the Femineer® Program.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thinking Skills</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can evaluate information.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I can visualize information.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I can understand a problem and find a solution.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I can find different solutions to a problem.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I can communicate information to other people.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Engineering Skills</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can code or program.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I can create a flow chart.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I am confident in my engineering skills.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I like STEM (Science, Technology, Engineering, Math).</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classroom</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel confident around the Femineer® students.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I feel confident around the Femineer® teacher(s).</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Background Questions (Please check the answer that best describes you.)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Which of the following best describes your race/ethnicity?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Asian American/Pacific Islander</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black/African-American</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hispanic/Latina</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native American/Alaskan Native</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White/Caucasian</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other: ________________</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you plan to study engineering in college?</td>
<td>Yes</td>
<td>No</td>
<td>Maybe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you plan to pursue a career in engineering?</td>
<td>Yes</td>
<td>No</td>
<td>Maybe</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The Cal Poly Pomona Institutional Review Board has reviewed and approved for conduct this research involving human subjects under protocol IRB-18-139.*