# Introducing Young Girls to Engineering through Summer Enrichment Programs

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*Abstract* – Women occupy nearly half the total United States workforce, but unfortunately only about 25% of Science, Technology, Mathematics and Engineering (STEM) professionals are women, with less than 10% being women of color. Research has shown that providing girls with a positive STEM-related experience in middle school can have a positive influence on their decision to pursue studies in STEM. In the absence of quality STEM curriculum in schools, particularly in urban areas with high proportions of minorities, summer enrichment programs can be instrumental in informing young girls about careers in STEM, particularly engineering, and help ensure they receive the academic preparation required to enter STEM-related college programs. The current study examines evaluation data collected from girls who attended such programs for multiple summers during the time period from 2006 to 2009, graduating from high school in 2014 and 2015 and provides follow-up date related to college attendance.

## Introduction

The demand for more professionals in the science, technology, engineering and mathematics (STEM) workforce continues to increase but not enough students are choosing to pursuing careers in the STEM fields to meet the increasing demand[1-3]. Two of the more critical reasons for this are the underrepresentation of women[4-8] and minorities[6, 8-9] and the inadequate academic preparation for college stemming from the absence of engineering topics in K-12 science and mathematics curriculum and instruction[10-14]. High-quality curricular materials relating science and mathematics to engineering, particularly for middle school students are limited and most teachers are ill-prepared to present engineering curriculum in their classrooms instruction[15-16] so often students find it difficult to make the connection between mathematics, science and engineering in the real world[17-18]. As a result, students often lack an interest in more advanced studies of science and mathematics and do not adequately prepare for STEM programs in college - especially engineering[1]. Academic preparation for college should begin as early as middle school, if not the late elementary grades[19-20] for students who choose to enter the fields of science, technology, engineering and mathematics (STEM), especially engineering. Unfortunately, the lack of engineering topics in K-12 curriculum and a general lack of public knowledge[20] about what engineering is and what engineers actually do, too many young students never consider studying engineering because the subject was never introduced to them[14-15, 19].

## The Underrepresentation of Women and Minorities

Summer Women occupy nearly half the United States workforce, but only about 25% of STEM professionals are women. Almost 75% of the scientists and engineers in the US are white and approximately 15% are Asian. When you consider other minority groups, only three percent are black, four percent are Hispanic and all other groups together add another three percent, such that underrepresented minorities account for only 10% of STEM professionals[21]. What is even more alarming is that only about 25% are women with less than 10% minority women[21].

Although high school graduation rates are increasing with a nationwide graduate rate of 78%[22] college enrollment rates have fallen, especially for low-income and minority students[23]. Hispanics are the nation's largest minority group with a lower high school graduation rate of approximately 70%[22, 24]. The graduation rate for African American students is even lower, approximately 66%[22, 25]. Overall college enrollment rates decreased from 69% to 66% between 2008 and 2013 with an estimate of only 46% for low-income students[23]. Because high proportions of Hispanic and African American girls come from low-income backgrounds the college enrollment rate for those who graduate from high school are significantly lower than for other girls, particularly Caucasians[24-25]. High proportions of African American girls attend schools without quality resources or extracurricular activities and have limited opportunities to enroll in STEM courses or STEM-related activities[25]. Hispanic girls face the same low-income hurdles and are often placed in remedial classes because English is not their primary language[24].

**Educational Opportunities**

The Center for Pre-College Programs at New Jersey Institute of Technology (NJIT) has developed summer enrichment programs to increase academically talented students' interest in the fields of science, technology, engineering and mathematics (STEM). STEM programs of this type can be instrumental in informing young students about careers in STEM, particularly engineering, and help ensure they receive the academic preparation required to enter college programs in engineering or other highly technical fields in the absence of effective K-12 STEM curriculum in their schools. Middle and Elementary school programs span grades four to eight, with each grade level focused on a different field of engineering. Because NJIT is located in the large urban city of Newark, surrounded by other urban areas with high proportions of minorities, the students who attend these programs are predominately Hispanic and African American.

One series of programs, Woman in Engineering and Technology, which is still called FEMME for the original name, "Females in Engineering: Methods, Motivation and Encouragement", was designed specifically for young girls in an effort to increase the number of women interested in engineering and other technological careers[26-27]. Not only is middle school a critical time for all students to start thinking about their future and make the appropriate academic choices, it is particularly important for young girls because until the high school years girls and boys do not differ much in technical abilities years but rather in their attitudes toward technological careers like engineering[28-29]. By the time some girls reach high school they begin underestimating their own technical abilities and start placing more importance on being popular rather than academic performance[30-31]. They tend to enroll in fewer mathematics and science courses, and as a result lack the academic background necessary to even apply to STEM programs in college[31-32]. Research has found that providing young girls with a positive STEM-related experience in middle school, before they develop negative attitudes or lose interest can have a positive influence on their decision to pursue studies in STEM[33-35]. Although, research on the benefits and relative effectiveness of single-gender education remains inconclusive, considerable research describe many benefits of single-gender education for girls in addition to improved academic performance, including increased confidence, being more likely to ask questions, and maintaining behaviors that tend to disappear due to male dominance in the classroom.

Early evaluations of the program(s) were positive and mostly formative in nature, but recent evaluations have become more rigorous with positive results. Girls who participated in the programs have been found to have significantly more positive attitudes toward STEM, particularly engineering, significantly more knowledge about careers in engineering and what engineers actually do compared to other students from similar backgrounds. Recent, more qualitative evaluations using the Draw an Engineer test to examine girls' perceptions of engineers including gender attributions and their own self-efficacy have found interesting and positive results. Data from evaluations conducted during the last 6 years are being synthesized to demonstrate the positive and motivation effects programs of this type can have on young girls.

The focus of the current paper is an examination of evaluation data collected from girls during the summer of 2008 who attended such programs for multiple summers during the time period from 2006 to 2009, who would have graduated from high school in 2014 or 2015, and provides follow-up data related to college attendance. There were 40 girls who participated in either FEMME 5 or FEMME 6 (meaning they had completed the $5^{th}$ or $6^{th}$ grade) during the summer of 2008. There were a total of 50 girls who participated (25 in each program) but only 22 in FEMME6 and 18 in FEMME5 that attended for multiple summers before entering high school. Sixty percent (n=24) of the girls were Hispanic, 27% (n=11) were African American, 8% (n=3) identified as biracial, only 5% (n=2) were Caucasian (see Table I).

**Evaluation**

During the summer of 2008 girls completed the Middle School Attitudes to and Knowledge about Engineering Survey (MATES)[36] and the Draw an Engineer Test[37] at the beginning (pre-measures) and the end of the program (post-measures). The girls were also asked about whether they had heard about jobs in math, science and engineers before and/or if their parents, teachers or school counselors had talked to them about jobs in engineering. Possible responses were Never, 1-2 times or Many times.

In addition to attitudes towards engineering, the MATES measures knowledge about careers in engineering with a multi-part open-ended question that requires students to "Name five different types of engineers" and to "give an example of the work done by each type". Each type of engineer is coded "1" for correct and "0" for incorrect. Possible total scores range from zero to five. Each example of the work they do is coded "2" for completely correct, "1" for partly correct, and "0" for incorrect. Possible total scores range from zero to ten.

The Draw an Engineer Test is a semi-qualitative measure of young students perceptions of who engineers are and what they actually do[38-39]. The girls were asked to draw a picture of an engineer at work and write a short sentence about what the engineer in their picture was doing. Previous experience has shown that purely quantitative measures derived from surveys such as the MASTEM are not always sufficient to capture cognitive changes in students' perceptions about engineers particularly for young girls when examining the issues of gender and whether they perceive women can be engineers.

More than half the girls indicated their parent had talked them about jobs in engineering; 30% many times (see Table I). Unfortunately the same is not true for their teachers or school counselors. Although 70% of the girls reported that a teacher had talked to their class about jobs in engineering, most girls (83%) reported that their teachers had never talked to them personally about jobs in engineering and sadly, only 3 girls (<10%) reported that their school counselor had talked to them about jobs in engineering. So although their parents talked to them about engineering jobs, most of the girls were not learning about jobs in engineering from school.

**Table I**
**Summary of Who has talked to the Girls about Jobs in STEM**

How many times have your parents/guardian talked to you about engineering as a job?

| | Never | 1-2 times | Many times | Total |
|---|---|---|---|---|
| Hispanic | 9 | 8 | 7 | 24 |
| African American | 4 | 3 | 4 | 11 |
| Bi-Racial | 1 | 1 | 1 | 3 |
| Caucasian | 1 | 1 | | 2 |
| Total | 15 | 13 | 12 | 40 |

How many times has one of your teachers talked to **YOU** personally about engineering as a job?

| | Never | 1-2 times | Many times | Total |
|---|---|---|---|---|
| Hispanic | 19 | 5 | | 24 |
| African American | 9 | 2 | | 11 |
| Bi-Racial | 3 | | | 3 |
| Caucasian | 2 | | | 2 |
| Total | 33 | 7 | | 40 |

How many times has one of your teachers talked to your whole class about engineering as a job?

| | Never | 1-2 times | Many times | Total |
|---|---|---|---|---|
| Hispanic | 4 | 19 | 1 | 24 |
| African American | 4 | 7 | | 11 |
| Bi-Racial | 2 | 1 | | 3 |
| Caucasian | 2 | | | 2 |
| Total | 12 | 27 | 1 | 40 |

How many times has one of your school counselors talked to you about engineering as a job?

| | Never | 1-2 times | Many times | Total |
|---|---|---|---|---|
| Hispanic | 22 | 2 | | 24 |
| African American | 10 | 1 | | 11 |
| Bi-Racial | 3 | | | 3 |
| Caucasian | 2 | | | 2 |
| Total | 37 | 3 | | 40 |

## Knowledge of Careers in Engineering

Experience has shown that students' attitudes toward STEM do not often appear to increase significantly after enrichment programs due to prior positive attitudes that lead them to enrol initially although knowledge about engineers and careers in engineering usually show significant improvement (See Table II). Approximately 30% of the girls were not able to correctly name even one type of engineer at the beginning of their 2008 program. This percentage is slightly higher than for most students beginning a program but for some of these girls this was not their first program and most indicated their parents had talked to them about jobs in engineering . But by the end of the program 95% were able to name at least one type of engineer (most at least 2 or 3), with 30% being able to name four or five types which is a significant increase ($\chi^2_2 = 13.6$, $p<.01$) (See Table II, Part 1).

Only 40% of the girls were able to give even partly correct examples of the kind of work that engineers before beginning their program but by the end 95% were able to give at least some correct or partly correct examples of the kind of work a specific type of engineer does, which is also a significant increase ($\chi^2_1 = 20.0$, $p<.01$) (See Table IV, Part 2).

**Table II**

**Changes in the Response to the Knowledge of Engineering Question**

| | Part 1<br>Name 5 types of Engineers<br># of Correct Responses | | | Part 2<br>Give examples of the work done by each type<br>Total number of Points* | |
|---|---|---|---|---|---|
| | 0 | 1-3 | 4-5 | 0 | 1-5* |
| Beginning of Program | 32% | 60% | 8% | 60% | 40% |
| End of Program | 5% | 65% | 30% | 5% | 95% |
| | $\chi^2_2 = 13.6$, $p<.01$ | | | $\chi^2_1 = 20.0$, $p<.01$ | |

* No student scored more than 4 points at the beginning or 5 points at the end so this category was collapsed into 1-5 for the Chi-Square Test

## Preceptions of Engineers from Drawings

Students' drawings of Engineers at Work are summarized using the DET checklist[65]. The checklist begins with an examination of the engineer to check the species, actual presence, gender, skin color, and other attributes, like glasses, lab coats, crazy hair or other clothes. The location of the engineer (inside, outside, in space, underwater) is coded and there is a list of inferred actions that can be indicated, like fixing, designing, teaching, experimenting, building, or even NO action can be indicated. The types of other objects in the drawing are also coded, for instance, the presence of other people, animals, symbols that would indicate math or chemistry, airplanes, computers, cars, trains, signs of thinking, etc. Changes in the gender attributions of the engineer and the inferred action (i.e. what the engineer is actually doing) can also be determined by considering verbiage in the girls' sentence about what the engineer in the picture is doing. Verbiage in the sentences is examined for the use of it, he, she, my, or the in conjunction with the drawing of the engineer. Students often draw a stick figure with no gender or a mechanic\worker with only legs protruding out from under a rocket or car. When a stick figure, androgynous person or partly hidden person is drawn and described as "it", "my engineer" or "the engineer" in the sentence then the gender of the engineer is coded as unknown. Verbiage in the sentences was also examined for words to help support designing, creating, testing, problem solving as opposed to building, fixing, operating, driving etc.

Seven pairs of pre-post drawings follow on the next few pages to show examples of changes in gender attribution, misconceptions and development of more detailed understandings of what engineers actually do.

The drawings in Figure 1 a and b were drawn by a post-fifth grader who attended the FEMME for the first time. Her drawings are simple and her engineers are stick figures but clearly show a change in perception from a misconception that engineers fix cars to an accurate perception that engineers design computer games and a change in gender attribution from male to female.


Figure 1a. Male fixing a car

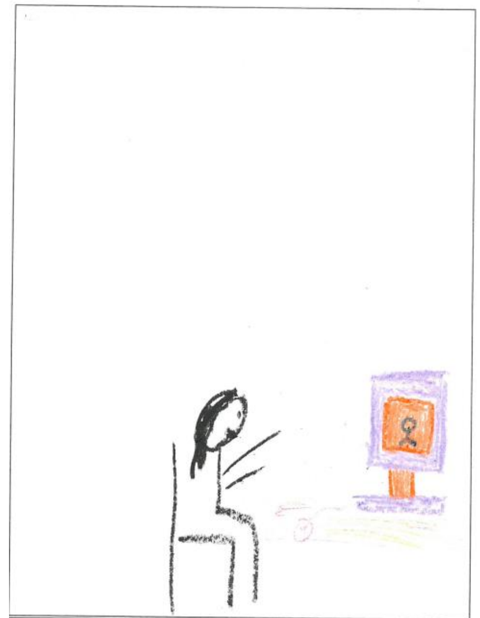

Figure 1b. Female designing a computer game

The drawings in Figure 2 a and b were drawn by a post-sixth grader who was attending her second FEMME program. Her drawings are more detailed and both engineers are "women. In her first drawing the engineer is welding something she needs to for her test dummy which is a little sketchy but her second drawing is of an engineer "building a prototype of the roller coaster she designed showing a much better understanding of what some engineers do.

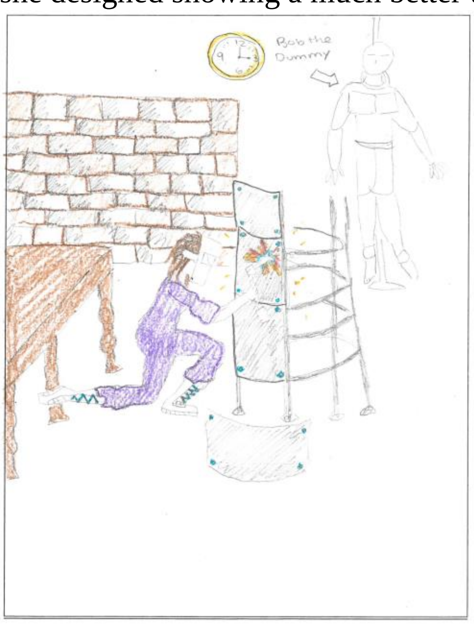


Figure 2a. Female welding

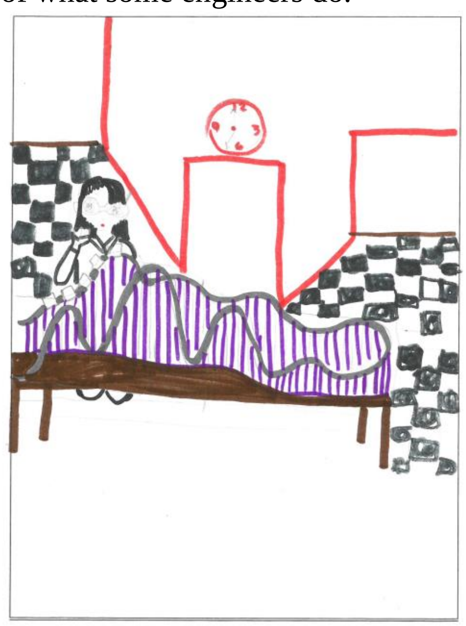

Figure 2b. Female building a prototype

The drawings in Figure 3a and b were drawn by another post-fifth grader attending her second FEMME program. The engineer in her pre drawing is "fixing a wheel on his a train". The two engineers in her post drawing were inspecting the bridge they built. Although she did not say they designed it, she said they built it and were inspecting it rather than fixing it. This shows not just a more accurate understanding of engineering it also shows that she thinks engineers can work as a team. She did not identify their gender but one appears to be male the other female.

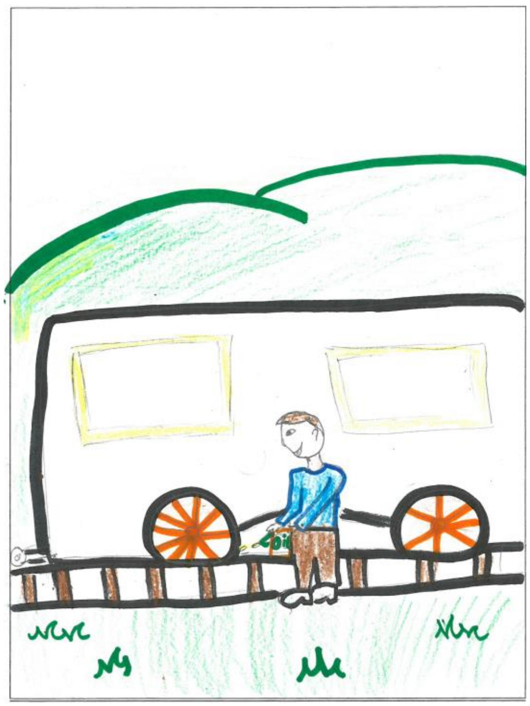

Figure 3a. He is fixing a wheel on the train

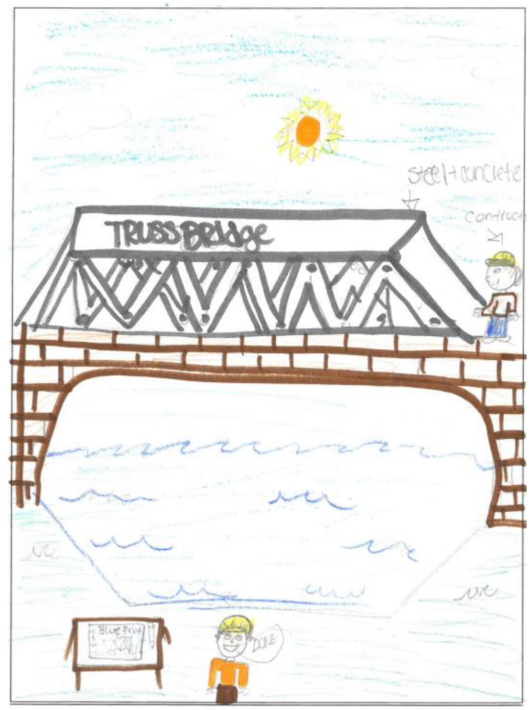


Figure 3b. Female building a prototype

The drawings in Figure 4a and b were drawn by a post sixth-grader grader attending her first FEMME program. The engineer in her pre drawing is "a mechanic putting oil in his car". The engineer in her post drawing is "a mechanical engineer reviewing the blue prints for a roller coaster to be built to make sure everything will go right". Although she did not identify the engineers' gender "the engineer" appears female showing a better conception of engineering and a change in gender attribution.

Figures 5a and b were also drawn by a post sixth-grader grader, but she was attending her third FEMME program. The engineer in her pre drawing is male "mixing and testing chemicals for a living" and "studying what will happen". She labels her engineer as a Chemical Engineer and her depiction of what he is doing does not necessarily show an accurate understanding of what a chemical engineers does but it does not show an inaccurate misconception. One would hope that after two FEMME programs her understanding might be better but her post drawing does show a well-developed understanding. The Mechanical Engineer is "inspecting the support system of the roller coaster he designed".


Figure 4a. Male mechanic putting oil in a car

Figure 4b. Female(?) Reviewing blueprints

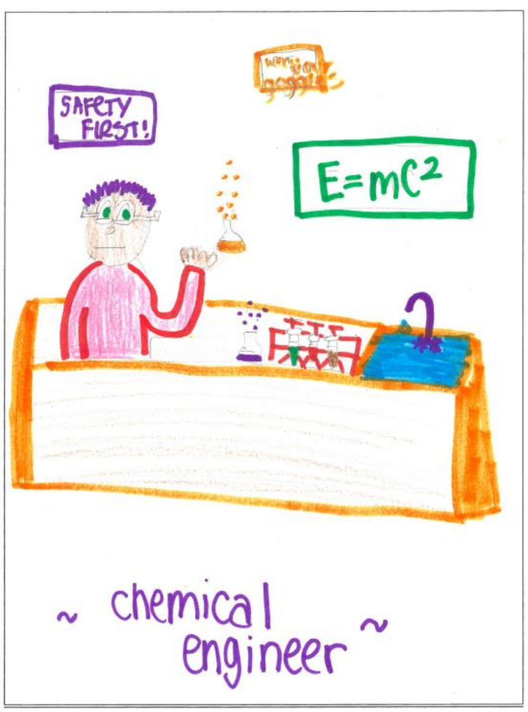


Figure 5a. Mixing and testing Chemicals

Figure 5b. Inspecting support system of the roller coaster he designed

Figures 6a and b were drawn by a post sixth-grader grader attending her second FEMME program. The gender of the engineers in both her drawing is unknown. Both are drawn from behind and there is no identifying label in her sentences. The engineer in the pre drawing is "looking at blue prints and telling the crane operator where to put the beams" which does not show an understanding of what an engineer does but her post drawing does, the "engineer is building a prototype of a new invention".

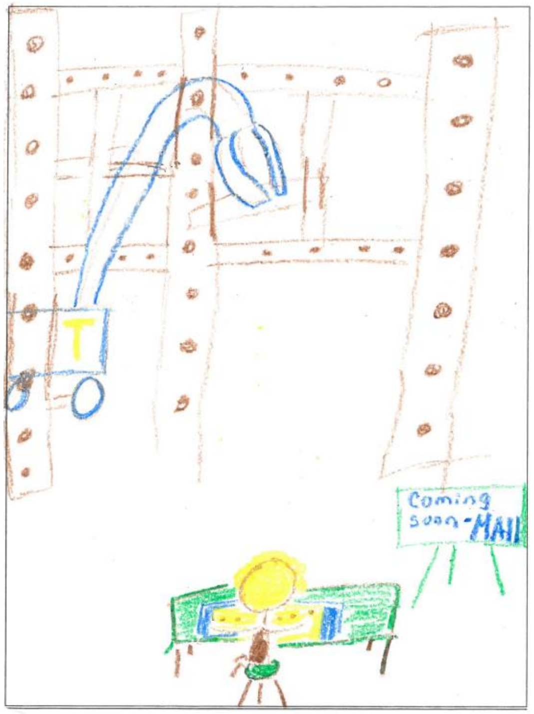


Figure 6a. Looking at blue prints, directing crane

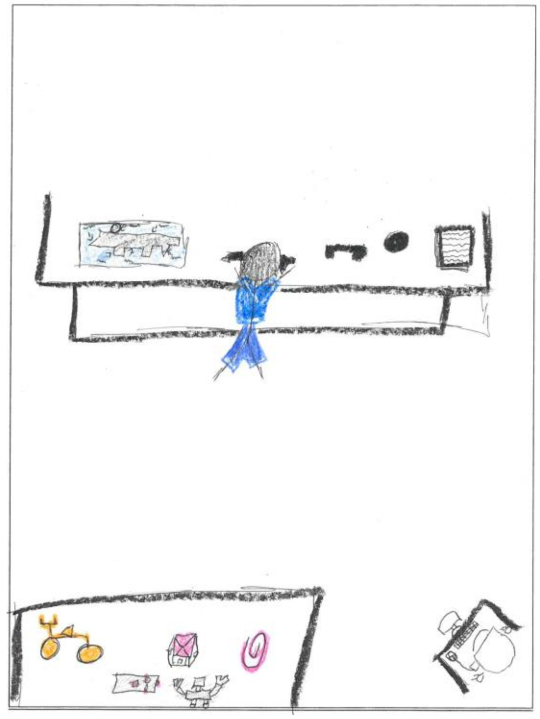

Figure 6b. Building prototype of invention

Figures 7a and b were also drawn by a post sixth-grader attending her second FEMME program. The female engineer in her pre drawing is "making a model of building to be constructed" from the blue prints and the female engineer in her post drawing is "improving something". She is "identifying a problem" "defining it" and "Building a model of a design solution". Both of her drawings show a mature conception of engineering and a clear notion that they can be female.

The last Figures, 8a and b were also drawn by a post sixth-grader grader attending her second FEMME program. The female engineer in her pre drawing is "trying an experiment to put 4 engines in a car to improve performance and speed". The male engineer in her post drawing is "following the design process in constructing a prototype of a new roller coaster". Again, both drawings show a mature conception of engineering, hopefully she has a clear notion that engineers can be female since the pre-engineer is female even though the post engineer is male.

**Follow up College Attendance**

The girls included in the current study (who participated in the evaluation conducted in 2008) were identified because they attended at least 2 but as many as 4 or 5 FEMME programs. The previous data were summarized to review the direct outcomes measured when they attended the programs. Although the results were quiet positive, do they translate into college enrollment?

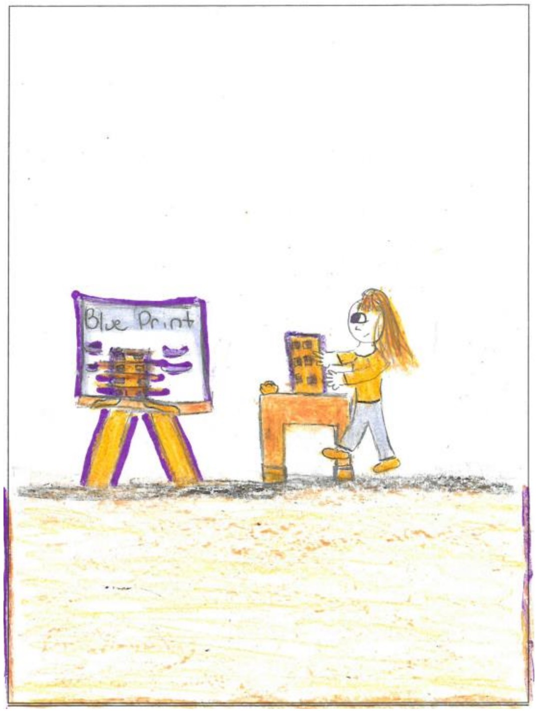


Figure 7a. Female building a model from blue prints

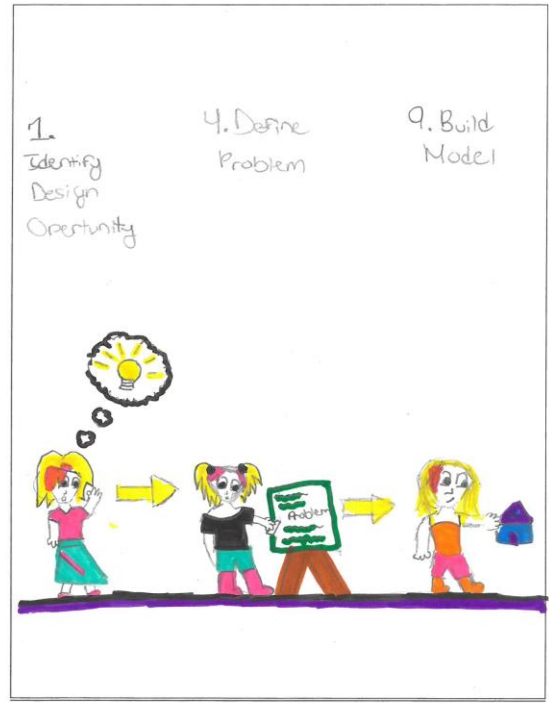


Figure 7b. Female following the design process

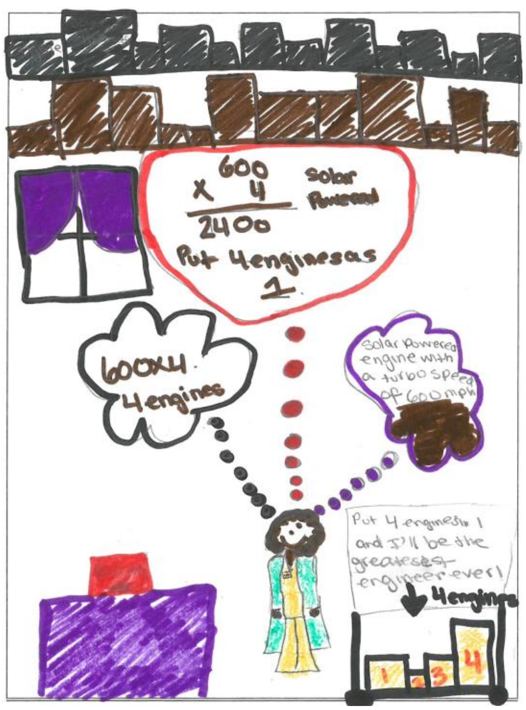


Figure 8a. Female trying to improve an engine


Figure 8b. Male following the design process

The authors are trying to contact the girls and/or their families to collect information about college attendance and choice of major but since these girls came from low-income, urban areas most have moved and no current contact information is available. But if students are currently enrolled in an institution of higher education they can be identified through the National Student Clearinghouse (www.studentclearinghouse.org) with their full name and date of birth.

Of the 40 girls identified we did not have correct birth dates for 3 of the 22 girls in FEMME 6 and 4 of the 18 girls in FEMME 5. The 33 (19 from FEMME 6 and 14 in FEMME 5) girls for which we had correct birthdates we were able to look them up in the National Student Clearinghouse to determine if they are currently enrolled in college and which college or university they are attending, although until they graduate we will not know which majors they have chosen to determine if they appear to be pursuing a career in the STEM fields.

Of the 19 girls from the 2008 FEMME6 program (who attended at least one other summer FEMME program, 16 of them are currently enrolled in college. Four are attending local community colleges in New Jersey, 2 are attending Monmouth University in NJ, 2 are attending Temple University in Philadelphia, 2 are attending New Jersey City University, others are attending Seton Hall, Worcester Polytechnic Institute, Brown University, Howard University in DC, Colgate and University of New Haven, CT. Another girl had been enrolled in a community college and withdrew after a semester. Hopefully it was for financial reasons and she will be able to return soon, rather than a desire to quit.

Of the 14 girls from the 2008 FEMME5 program (who attended at least one other summer FEMME program, 11 of them are currently enrolled in college. Three are attending local community colleges in New Jersey, 2 are attending Muhlenberg College in PA, others are attending Jersey City University, Wesleyan College, Yale University, Columbia, Montclair State University and the University of Pittsburg.

## Discussion

Across the two groups of girls, 27 of the 33 (82%) for which we had sufficient information to track them through the National Student Clearinghouse (www.studentclearinghouse.org) are currently enrolled in either a two-year or four-year college or university. Estimating that approximately 82% of the girls who were predominantly Hispanic and African American from low-income urban areas were enrolled in college indicates that not only did these girls exceed the expected college enrollment rates they far exceeded the high school graduation rates of 71% and 66%, respectively. These girls were fortunate in that many of them received assistance from their schools due to the on-going partnerships with NJIT. The Center for Pre-College Programs also works to find funding to help girls who wish to attend FEMME programs.

Continued review of evaluation data collected by the Center for Pre-College Program over the last 10 years should result in more study similar to the current study and will include continued follow-up of college attendance and graduation, including majors to further promote the positive effects of involving young girls in pre-college engineering programs particularly minorities from low-income communities as so many research recommend[1,2,24,25].

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