Comparisons of a Female-Only, Male-Only, and Mixed-Gender Engineering Enrichment Program for 4th Graders

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Abstract

The benefits and relative effectiveness of single-gender education are still unclear and more research is necessary before strong conclusions can be formed. Results of previous evaluations comparing aspects of female-only summer enrichment programs to equivalent mixed-gender programs has shown female-only programs to be particularly effective in educating young girls about engineering and positively influencing their perceptions of engineers and attitudes toward engineering as a career. Subsequent evaluations comparing single-gender vs mixed-gender programs including male-only programs had mixed results. The current study is a more rigorous examination of gains in content knowledge and takes a closer look at the issues of self-efficacy, gender equity and qualitative perceptions of engineers using the Middle School Attitudes toward Engineering and Knowledge of Engineering Careers Survey and the Draw an Engineering Test in equivalent post 4th grade female-only, male-only and mixed-gender programs. Previous evaluations included higher-grade programs with some returning students that had already participated in other program(s) so they had some prior knowledge of engineering and had possibly participated in a program of a different gender composition. In addition to comparisons among gains in content knowledge, comparisons between characteristics of students drawing from the Draw an Engineer Test and responses to the Attitudes toward Engineering and Knowledge of Engineering Careers Survey found significant differences among the three gender group programs in terms of self-efficacy and gender attribution of engineers.

Introduction

Despite the fact that the demand for more professionals in the science, technology, engineering and mathematics (STEM) workforce continues to increase, there are not enough students pursuing careers in these fields to meet the increasing demand[1-4]. Among the many contributing factors two of the most critical are the underrepresentation of women[5-9] and minorities[2, 7, 9-10] and inadequate academic preparation for college and workforce readiness starting with the absence of engineering topics in K-12 science and mathematics curriculum and instruction[11-17]. Proper academic preparation for college must begin as early as middle school, if not the late elementary grades[18-19] for students who choose to enter the fields of science, technology, engineering and mathematics (STEM), especially engineering[16]. But, unfortunately due to the lack of engineering topics in elementary and middle school 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.

The Underrepresentation of Women and Minorities

Nearly 75% of the scientists and engineers in the United States 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]. Women occupy nearly half the US workforce but less than 25% of the STEM workforce[2, 5]. Ironically, young boys and girls do not differ much in technical abilities or interest in STEM during the early years of their education, but girls develop negative attitudes toward technological studies in the later high school years[22-24]. 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[20, 25-27].

Inadequate Academic Preparation and Lack of Engineering Topics in K-12 Science and Math

High-quality curricular materials relating science and mathematics to engineering, particularly for middle school students are limited. Most teachers have not been trained to incorporate engineering topics into relevant classroom instruction so often students find it difficult to make the connection between mathematics, science and engineering[28-30] when teachers do try to present engineering concepts. As a result, too many students lack an interest in more advanced studies of science and mathematics and are not adequately prepared to enter STEM programs in college - especially engineering – even if they do develop an interest in a STEM career later[2]. This is unfortunate because today in the 21st century, knowledge of science, technology and engineering are not only essential workforce skills, they are necessary to make informed decision in most aspects of everyday life like which form of energy to use in your house or whether to buy a gasoline, diesel or electric car.

Science, mathematics and technology classes are not always synthesized and often students are not able to see how classroom lessons relate to real life[31]. Increasing the presence of engineering in K-12 education with practical hands-on applications of science and mathematics as recommended in the *Next Generation Science Standards* (NGSS)[32] should be a priority for educators[12, 19, 33-35] but most teachers are not familiar with engineering and engineering applications and are ill-prepared to present engineering curriculum in their classrooms[36-37].

Background

At the Center for Pre-College Programs (CPCP) at New Jersey Institute of Technology (NJIT) summer enrichment programs have been developed to increase high achieving students' interest in the fields of science, technology, engineering and mathematics (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. Available Middle and Elementary school programs span grades four to eight, with each grade level focused on a different field of engineering. The fourth grade program gives students an introduction to environmental engineering, the fifth grade program covers aeronautical engineering, grade six mechanical engineering, seventh grade chemical engineering and eighth grade bio-medical engineering. Students attend classes and participate in hands-on activities designed to introduce students to real-life applications of engineering.

One series of programs, Woman in Engineering and Technology, still called FEMME for the original name, "Females in Engineering: Methods, Motivation and Experience", was designed specifically for young girls in an effort to increase the number of women interested in engineering and other technological careers[38-39]. 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[40-41]. 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[42-43]. 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[43-44].

Overall, research on the benefits and overall effectiveness of single-gender education remains inconclusive[45-52]. Considerable research describes numerous benefits of single-gender education for girls, in addition to increased 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[49]. But more recent reviews of single-gender education caution that much of the research is not rigorous or scientifically based, and tends to focus on private and Catholic schools[48] and provide no strong conclusions supporting or dismissing the overall benefits[50]. More recently researchers have suggested there should be a clear rationale with specific goals for single-gender education[53-55]. Summer enrichment programs like FEMME, designed with the goal to increase the number of women interested in engineering and other technological careers in an atmosphere free from male dominance are consistent with this recommendation and prior evaluations of the FEMME program[46, 56-57]. Girls who have participated in FEMME programs have been found to have significantly more positive attitudes toward STEM, particularly engineering, and significantly more knowledge of engineering careers compared to other students (both male and female) from similar backgrounds[58-59]. Follow-up surveys of FEMME girls who have completed high school indicate that approximately 70% continue on a career path in STEM[56].

The addition of male-only programs equivalent to the FEMME and mixed-gender programs prompted more in-depth evaluations comparing the benefits and relative effectiveness of single-gender vs mixed-gender programs and specific comparisons among female-only, male-only and mixed-gender programs with mixed results[60-61]. Few meaningful differences were found between the males and females within the programs in terms of increased content knowledge or attitudes toward engineering although, consistent with conclusion drawn from reviews of recent research, marked differences were found among the three different gender grouped programs in terms of classroom climate and student interactions in the classroom[60-61]. And while no differences were found for male students, comparisons between the female students in the female-only programs and the mixed gender program did however find some potentially meaning differences in self-efficacy and perceptions of engineers related to issues of gender identity[61].

The current investigation was designed to be a more rigorous examination of gains in content knowledge and look more closely at the issues of self-efficacy, gender equity and qualitative perceptions of engineers using the Middle School Attitudes toward Engineering and Knowledge of Engineering Careers Survey (MATES)[62] and the Draw an Engineer Test (DET)[63] in equivalent post 4th grade female-only, male-only and mixed-gender versions of an environmental science and engineering program held during the summer of 2015 at NJIT. The previous evaluations[60-61] included higher-grade programs with some returning students that had already participated in another program so they had some prior knowledge of engineering and had possibly participated in a program of a different gender composition. In addition, the male to female ratio in the mixed-gender program in the current study (48% female, 52% male) is much closer to 50/50 than in the previous evaluation.

Evaluation

The summer began with 24 students in each of the single gender programs (male-only and female-only) and 23 students in the mixed gender program, 11 females and 12 males (N=71 total). Table 1 is a summary of the ethnic diversity of each group. Due to sporadic absenteeism on the days that the pre and post measures were taken most analyses are based on approximately 22-23 students per program (N=69 or 68 for most analyses).

Table I

Ethnicity by Program

	------ Program ------		
	Male-only	Female-only	Mixed gender
Caucasian	2	4	4
African American	3	4	2
Hispanic	15	9	13
Asian Indian	3	2	4
Bi-racial	1	2	0

Students completed; 1) the MATES[62], 2) separate grade-appropriate content knowledge tests of engineering, mathematics, computer technology and communications (each developed specifically for the environmental science and engineering program), and 3) the DET[63] at the beginning (pre-measures) and the end of the program (post-measures). In addition, students were asked about whether they had heard about jobs in math, science and engineering before and/or if their friends, parents, teachers or school counselors had talked to them about jobs in engineering. Possible responses were Never, 1-2 times or Many times (see Table II).

Responses indicate that most student had heard about jobs in Math and Science from television although fewer had heard about engineering and only about half had talked to their friends about jobs in engineering. Approximately 60% of the students reported that their parent had talked to them about jobs in engineering; 40% many times. Sadly, less than 25% reported that their teacher or school counselor had talked to them about jobs in engineering and only about 50% reported that their teacher talked to the class. No significant differences were found in students' responses among the three programs (using Chi-Square Tests of Independence) indicating the programs appeared to start out similar in terms of prior knowledge of engineering.

Table II
Summary of Where Students may have heard about Jobs in STEM

How many times have you heard about jobs in Math and Science on TV/Movies?

	Never	1-2 times	Many times	Total
Mixed-gender	2	7	14	23
Single-gender males	7	6	8	21
Single-gender females	2	11	11	24
Total	11	24	33	68

How many times have you heard about jobs in Engineering on TV/Movies?

	Never	1-2 times	Many times	Total
Mixed-gender	6	8	9	23
Single-gender males	8	8	6	22
Single-gender females	6	9	9	24
Total	20	25	24	69

How many times have you & friends talked about jobs in Engineering?

	Never	1-2 times	Many times	Total
Mixed-gender	11	8	4	23
Single-gender males	12	7	3	22
Single-gender females	12	6	6	24
Total	35	21	13	69

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

	Never	1-2 times	Many times	Total
Mixed-gender	17	5	1	23
Single-gender males	17	5	0	22
Single-gender females	16	6	2	24
Total	50	16	3	69

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
Mixed-gender	9	11	3	23
Single-gender males	13	8	1	22
Single-gender females	11	10	2	23
Total	33	29	6	68

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

	Never	1-2 times	Many times	Total
Mixed-gender	17	5	1	23
Single-gender males	20	2	0	22
Single-gender females	18	5	1	24
Total	55	12	2	69

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

	Never	1-2 times	Many times	Total
Mixed-gender	4	8	11	23
Single-gender males	10	6	6	22
Single-gender females	12	2	10	24
Total	26	16	27	69

Middle School Attitudes to and Knowledge about Engineering Survey

The MATES[62] was developed and revised[66] to measure middle school students' attitudes toward mathematics, science, especially engineering, and their knowledge about careers in engineering (i.e. what engineers actually do). In addition to all over attitudes toward mathematics, science and engineering, six subscales have been identified to measure Interest in engineering: stereotypic aspects (Stereotypic), Interest in engineering: non-stereotypic aspects (Nonstereotypic), Negative opinions (Negative), Positive opinions (Positive), Gender Equity (Gender) and Self-Efficacy for Problem Solving and Technical Skills (i.e. skills needed for engineering).

The MATES also 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

The Draw an Engineer Test was used as a semi-qualitative measure of young students perceptions of who engineers are and what they actually do[63-65]. Students were asked to draw a picture of an engineer at work and write a short sentence about what the engineer in the picture was doing. A checklist is used to summarize the location and appearance of the engineer (gender, color, etc.), others objects, machines, and/or people in the picture as well as what is going on in the picture (inferences of action)[65]. Previous research has found that purely quantitative measures derived from surveys such as the MASTEM are not always sufficient to capture cognitive changes in students' perceptions about engineers.

Results

Attitudes toward STEM and Content Learning

Three-factor repeated measures analysis of variance techniques were used to test for changes in students' self-efficacy, attitudes toward engineering and content knowledge as measured by the MATES[62] and program specific content knowledge tests which included mathematics, engineering, computers and communication. Two between subject factors, gender and program (single-gender vs. mixed gender) and one within subject factor (time from beginning to the end of the program) were used to test for differential effects due to gender or/and program. All students in each of the three programs showed significant and substantial increases in all areas of content knowledge from the beginning to the end of their respective programs (See Table III).

Of interest in this particular evaluation are possible interactions between gender and program indicating different outcomes (changes from pre- to post-) for males and females based on which of the programs they participated in, a single- or mixed-gender program. For communications and mathematics no significant interactions were found but significant interactions were found for engineering and computer applications (See Table III).

TABLE III

Means and Standard Deviations For Content Knowlegde Tests and MATES Scale(s)

CONTENT KNOWLEDGE			N	Beginning Mean (SD)	End Mean (SD)	F^{+} p-value
Engineering	Single gender:	Males	24	52.5 (12.1)	81.9 (9.5)	
		Females	21	40.3 (10.3)	92.3 (10.4)	$F_{1.64}=5.76$*
	Mixed gender:	Males	12	50.6 (12.0)	90.3 (8.1)	p=.019
		Females	11	45.4 (10.6)	90.0 (7.2)	
Communications	Single gender:	Males	24	64.9 (13.8)	84.8 (9.2)	
		Females	21	65.2 (11.6)	81.3 (13.6)	$F_{1.64}=1.56$
	Mixed gender:	Males	12	66.5 (13.7)	77.1 (13.4)	p=.220
		Females	11	65.9 (14.3)	82.0 (7.7)	
Computers	Single gender:	Males	22	57.9 (11.3)	75.9 (13.1)	
		Females	21	49.3 (9.5)	75.0 (12.5)	$F_{1.61}=4.03$*
	Mixed gender:	Males	12	55.8 (10.8)	81.3 (13.6)	p=.047
		Females	10	58.0 (10.6)	78.5 (13.7)	
Mathematics	Single gender:	Males	24	39.1 (16.7)	75.4 (16.7)	
		Females	21	24.7 (12.6)	71.3 (11.1)	$F_{1.64}=0.09$
	Mixed gender:	Males	12	30.1 (17.3)	74.7 (11.8)	p=.770
		Females	11	25.5 (16.7)	75.7 (11.8)	
MATES						
Overall Attitudes	Single gender:	Males	22	3.3 (0.6)	3.3 (0.6)	
		Females	21	3.5 (0.5)	3.6 (0.6)	$F_{1.61}=0.10$
	Mixed gender:	Males	11	3.8 (0.5)	3.9 (0.6)	p=.755
		Females	11	3.6 (0.5)	3.5 (0.6)	
Subscales						
Positive	Single gender:	Males	22	3.1 (1.0)	2.9 (1.0)	
		Females	21	2.9 (0.9)	3.1 (1.2)	$F_{1.61}=0.10$
	Mixed gender:	Males	11	3.5 (1.0)	3.5 (0.9)	p=.355
		Females	11	2.9 (1.0)	3.0 (0.8)	
Negative*	Single gender:	Males	22	2.0 (0.3)	1.8 (0.5)	
		Females	21	1.6 (0.5)	1.5 (0.6)	$F_{1.61}=0.81$
	Mixed gender:	Males	11	1.8 (0.3)	1.5 (0.5)	p=.372
		Females	11	1.7 (0.3)	1.7 (0.5)	
Interest Stereotypic	Single gender:	Males	22	2.6 (1.2)	2.6 (1.2)	
		Females	21	2.8 (1.0)	2.6 (1.2)	$F_{1.61}=0.10$
	Mixed gender:	Males	11	2.9 (1.2)	3.0 (1.2)	p=.730
		Females	11	2.8 (1.2)	2.7 (1.3)	
Non-Stereotypic	Single gender:	Males	22	2.3 (1.3)	2.5 (1.3)	
		Females	21	2.9 (1.0)	3.3 (1.2)	$F_{1.61}=0.28$
	Mixed gender:	Males	11	3.0 (1.3)	3.5 (1.2)	p=.600
		Females	11	3.3 (1.4)	3.3 (1.4)	
Gender	Single gender:	Males	22	4.7 (1.1)	4.3 (0.9)	
		Females	21	3.8 (0.5)	4.2 (0.6)	$F_{1.61}=2.83$
	Mixed gender:	Males	11	4.4 (1.0)	4.4 (1.0)	p=.091
		Females	11	4.4 (1.0)	4.8 (1.0)	
Self-Efficacy	Single gender:	Males	22	3.3 (0.8)	3.2 (1.1)	
		Females	21	3.4 (0.7)	3.9 (0.8)	$F_{1.61}=3.87$
	Mixed gender:	Males	11	4.1 (0.6)	4.0 (0.8)	p=.049
		Females	11	3.8 (0.5)	3.5 (0.8)	

* Subscale items are phrased negatively, so a lower mean is desirable.

\+ F-statistics and p-values are for the interactions between program and gender

Content Knowledge

The increases from pre- to post- on the engineering content knowledge and computer application tests were significantly smaller for male students in the single-gender program than for the male students in the mixed-gender program while the increases from pre- to post- for the female students in the single-gender program were significantly greater than for the girls in the mixed-gender program. Male students in the single-gender programs increased an average of 30 points on the engineering test and 18 points on the computer test while the male students in the mixed-gender program increased an average of 40 and 26 points, respectively (i.e. smaller gains in the single-gender program). The opposite was seen for female students in the single-gender program, they increased an average of 52 points on the engineering test and 26 points on the computer test while the female students in the mixed-gender program increased an average of 45 and 20 points, respectively (i.e. greater gains in the single-gender program).

Attitudes toward Engineering

None of the students in any of the three programs showed significant changes in their overall attitudes towards engineering or in the interest, or positive and negative subscales but significant differences were found in self-efficacy and the gender-equity subscales (see Table III). It is not surprising to find non-significant changes in students' attitudes from the beginning to the end of enrichment programs such as these because students who attend enrichment programs typically start the program with fairly positive attitudes already. But the significant differences in the gender equity and self-efficacy subscales are interesting.

There was very little change in the self-efficacy scores for the males in either the mixed or single-gender programs but the self-efficacy scores for the female students in the single-gender program increased while the self-efficacy scores for the female students in the mixed-gender program decreased. Male students in the single- and mixed-gender programs decreased an average of .1 points on the self-efficacy scale while female students decreased .3 points and increased .5 points in the mixed- and single-gender programs respectively.

Knowledge of Careers in Engineering

Although students' attitudes toward STEM do not often appear to increase significantly after enrichment programs due to their prior positive attitudes, their knowledge about engineers and careers in engineering usually show significant improvement (See Table IV). Half of the students in the current study were not able to correctly name even one type of engineer before beginning their program, which is consistent with the fact that most of them reported that their parents and/or school personnel had not talked to them about jobs in engineering, but by the end of the program 75% could correctly name at least one type of engineer and 25% could name four or five types which is a significant increase ($\chi^2_4 = 11.8$, $p=.018$) (See Table IV, Part 1).

Only a small percentage (32%) of the students were able to give even partly correct examples of the kind of work that engineers before beginning their program but by the end 75% 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 ($\chi^2_2 = 8.2$, $p=.016$) (See Table IV, Part 2).

Table IV

Changes in the Response to the Knowledge of Engineering Question

	Part 1: Name 5 types of Engineers — # of Correct Responses			Part 2: Give examples of the work done by each type — Total number of Points*		
	0	1-3	4-5	0	1-4	5+*
Beginning of Program	50%	46%	4%	68%	32%	0%
End of Program	25%	50%	25%	25%	54%	21%
	$\chi^2_4 = 11.8$, p=.018			$\chi^2_2 = 8.2$, p=.016		

* Only 6 students scored 6 points and 2 students scored 9 points so this category was collapsed into the 1-4 category 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 (i.e. Human?), 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. The wearing of a hard hat and a face shield has been added to the attributes as it often hides the gender of the engineer.

For the purpose of the current paper, there will be a focus on the gender attributions of the engineer and changes in the attribution from pre- to post- and changes in inferred action (i.e. what the engineer is actually doing) by also considering verbiage in the students' 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.

Gender Attributions

The gender attributions of the engineer in relation to students' gender and the type of program, all-male, all female, or mixed-gender are summarized in Table V. None of the male students in either the single-gender or mixed gender programs drew female engineers at the beginning of their program. One male student in the single-gender program drew an engineer of unknown gender in his pre-drawing and a female engineer in his post drawing who he identified as Ellen Ochoa, who was a former engineer and astronaut. He wrote that she "used to be an engineer" and she appeared to be working on a monster truck in his drawing.

Of the 11 male students in the mixed gender program only 10 had pre- drawings, but most of them drew males engineers, pre and post, two drew engineers of unknown gender. Of the 22 male students in the single-gender program, 60% drew engineers of unknown gender at the beginning of the program and the other 40% drew male engineers. At the end of the program, 70% drew male engineers and the reamining 30% (with the exception of the student above) drew engineers of unknown gender (see Table V).

TABLE V
Summary of Gender Attributions of Engineers from the Draw an Engineer Test

	Single-gender				Mixed-gender			
	Male		Female		Male		Female	
Engineer's gender	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Male	9	15	7	3	8	9	5	7
Female	0	1	6	15	0	0	1	3
Unknown	13	6	9	3	2	2	5	1

Of the 11 female students in the mixed gender program only 1 drew a female engineer at the beginning of the program (and the end of the program), of the others half drew male engineers and the other half drew engineers of unknown gender. Two girls changed the gender of the engineer in their post drawing to female (one from a male and one from unknown gender). Three of the other four girls who drew engineers of unknown gender at the beginning of the program, changed the gender of their engineer to male in their post drawing. Four of the five girls who drew male engineers at the beginning of the program did not change and drew males engineers at the end of the program also.

Of the 21 female students in the single-gender program only six drew female engineers at the beginning of the program, seven drew male engineers and 9 drew engineers of unknown gender. At the end of the program 15 of the 21 girls drew female engineers. Three drew engineers of unknown gender and only three drew males engineers. The six girls who drew female engineers at the beginning of the program also drew female engineers at the end of the program, none of them changed their engineer to male.

What Engineers Do?

Drawings were also coded to describe the over all action or meaning of what the engineer was doing by examining the drawing and the verbiage in the sentence, although not all students wrote a sentence and the action and meaning had to be inferred from the drawing. Often those drawings were coded as working with hands if it looked like the engineer was doing something with their hands or nothing if the engineer appeared to be just standing there.

The major categories were; 1) Designing\Creating, 2) Making\Building, 3) Operating (machines, cars trains etc), 4) Experiment\Testing, 5) Problem Solving\Helping (make something better, solve problem), 6) Programing Computer, 7) Fixing, 8) Working with hands, and 9) Nothing. Table VI is a summary of how many students in each of the programs produced drawings that were classified into each of these nine categories.

Changes in action from nothing, fixing, working with hands, or operating machines\construction vheicles\Trains to designing, creating, experimenting, solving problems and even making or building indicate desirable improvements in students perceptions of what engineers do. Engineers don't fix wires, drive trains or work under cars they solve problems, they design, invent and develop ways to make peoples' lives better. Students' pre- and post- drawings were classified to fit into one of the nine categories above.

TABLE VI
Summary of What Engineers in the Draw an Engineer Test were Doing

	Single-gender				Mixed-gender			
	Male		Female		Male		Female	
Engineer was	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Designing\Creating	1	4	-	8	-	2	-	3
Making\Building	1	4	8	2	1	7	1	-
Experiment\Testing	2	-	-	3	-	-	-	-
Problem Solving\Helping	-	-	1	7	-	-	-	-
Programing Computer	-	-	3	-	-	-	-	1
Fixing	1	8	3	1	1	2	2	4
Working with hands	7	5	2	-	7	-	5	3
Operating Machines	2	-	-	-	-	-	-	-
Nothing	8	1	4	-	2	-	3	-

The females students in the single-gender program showed the most growth in their perceptions of what engineers do. Their drawings changed from engineers fixing and working with their hands or doing nothing to designing, solving problems and doing things to help people. Some of the female students in the mixed gender program changed their perceptions from nothing to designing but some also changed to fixing. Female students in the mixed gender program did not show the same kind of changes in perceptions and understanding that can be infered from the drawings by the female students in the single-gender program (see Table VI).

The males students in the single gender program showed some changes to desiging and making but also many drew pictures of engineers fixing cars or wires. Many of the males students in the mixed gender program changed their drawings from engineers working with their hands to making or building but did not describe the engineer as designing, problem soving or helping as the girls in the female only program (see Table VI).

Discussion

The three 4th grade summer engineering enrichment programs, females-only, males-only and a 50/50 mixed program, offered at New Jersey Institute of Technology's Center for Pre-College Programs during the summer of 2015 were effective in increasing all of the students' content knowledge in Engineering, Communications, Computer Applications and Mathematics. Although the programs followed the same curriculum and were taught by the same team of instructors, some differential effects were seen for students in the single-gender programs as opposed to the mixed-gender program.

The female students in the single-gender program showed greater improvements in engineering content knowledge and computer applications than the female students in the mixed-gender program. These results, in addition to significant increases in self-efficacy and an increase in girls' perceptions that women can be engineers, evidenced by the significant increase in the gender equity subscale of the Middle School Attitudes to Engineering Survey (MATES) and changes in gender attribution of engineers in the Draw an Engineer Test, strongly suggests that there are benefits in single-gender programs for female students. Self-efficacy is important for continued learning and persistence when learning becomes more complex or students have difficulty. Engineering remains a male dominated occupation and a strong sense of self will benefit any young girl who wishes to study engineering.

Although there were significant increases in the female students' self-efficacy scores and their responses to the gender equity items on the MATES there were no other significant increases in students' attitudes toward engineering overall, or within any of the three programs. Consistent with findings in previous research, it appears that while attitudinal measures such as the MATES are useful in evaluating the effectiveness of most engineering curriculum materials[66] or STEM programs[67] they are not necessarily the most effective measures of change that results from programs designed for high achieving students[57-60].

For the 4th graders in this study, the knowledge about engineers and careers in engineering question appears more informative as are other less objective measures of changes in students' understanding of what engineers actually do. Students in all the programs demonstrated further increases in their knowledge of engineers and careers in engineering as evidenced by the significant improvements in their answers to the knowledge of engineering careers question on the MATES from the beginning to the end of their respective program. A majority of the students in all three programs were able to correctly name more different types of engineers and give at least partly correct if not completely correct examples of the kind of work done by each at the end of the programs.

Results of the Draw and Engineer Test are the most telling. Clearly most of the female students who participated in the single-gender (all female) program learned that girls can be engineers. Curiously, percentage wise more of the female students in the single-gender program also drew female engineers at the beginning of the program. Perhaps just coming to the program to study engineering and seeing all the girls around themselves started to plant the seed that girls can be engineers.

Participating in the program appeared to be productive process for the females students in the single-gender program, not only did they develop the perception that they, girls, could be engineers as a group they developed a more accurate understanding of what engineers actually do. The engineers in their drawings were more detailed and more accurate. The engineers were designing and solving problems. Some of the engineers were described as "helping" make something "better" (improving peoples' lives) which is more consistent with women's preferred career choices, to help improve society. After explaining what the engineer in her drawing was doing, one young girl in the single-gender program wrote "I made my engineer a girl. The reason I made it a girl is because I think that girls can do anything"! Another wrote …"and I can't wait to become an engineer"!

Future Evaluations will include more in-depth comparisons between characteristics of students drawing from the Draw an Engineer Test[63] and their responses to the Middle School Attitudes to and Knowledge about Engineering Survey (MATES)[62] in an effort to better understand disparities found between these two measures in the current and previous evaluations.

References

[1] National Science Board. (2012). *Science and engineering indicators 2012*, Arlington, VA: National Science Foundation, 2012, (NSB1201.pdf).

[2] National Science Board. (2014). *Science and engineering indicators 2014,* Arlington, VA: National Science Foundation, 2014, (NSB1401.pdf).

[3] NACEWEB.org – National Association of Colleges and Employers. (accessed January 2016).

[4] American Society of Engineering Education. (2015). Engineering Education and the Science and Engineering Workforce. Public Policy Internet Website. http://www.asee.org.

[5] Beede, D., Julian, T., Langdon, D., McKittrick, G., Khan, B., & Doms, M. (2011). Women in STEM: A gender gap to innovation. Retrieved October 28, 2015 from http://www.esa.doc.gov/sites/default/ files/reports/documents/womeninstemagaptoinnovation8311.pdf

[6] Camera, L. (2015). Women Still Underrepresented in STEM fields, *U.S. News and World Report*, October, 21, 2015

[7] D'Onofrio, K. (2015). http://www.diversityinc.com/news/women-minorities-continually-left-behind-in-stem-jobs/, July 20, 2015.

[8] Hill, C., Corbett, C., and St. Rose, A. (2010). Why So Few? Women in Science, Technology, Engineering and Mathematics, Washington, D.C. Association of American Colleges.

[9] National Science Foundation, (2015). Women, Minorities, and Persons with Disabilities in Science and Engineering, Arlington, VA, NSF 15-311, January, 2015.

[10] Bidwell, A. (2105). STEM Workforce No More Diverse Than 14 Years Ago, *U.S. News and World Report,* February, 24, 2015

[11] Achieve, Inc. (2011). Achieve's sixth annual report on "Closing the Expectations Gap". Accessed at http://www.achieve.org/ClosingtheExpectationsGap2011

[12] Kimmel, H., Carpinelli, J., Burr-Alexander, L. and Rockland, R. (2006). Bringing Engineering into K-12 Schools: A Problem Looking for Solutions, *Proceedings of the 2006 American Society of Engineering Education Annual Conference & Exposition*, Chicago, IL. June.

[13] National Academy of Engineering (NAE) Committee on Engineering's Grand Challenges. (2012). Grand Challenges for Engineering, from http://www.engineeringchallenges.org/cms/challenges.aspx

[14] National Research Council. (2011). A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas, National Academy Press, Washington D.C.

[15] President's Council of Advisors on Science and Technology (PCAST). (September, 2010). Prepare and Inspire: K-12 Science, Technology, Engineering and Math (STEM) education for America's Future. Download from http://www.whitehousegov/ostp/pcast.

[16] President's Council of Advisors on Science and Technology (PCAST). (February, 2012). Engage to Excel: Producing one Million Additional College Graduates with degrees in Science, Technology, Engineering and Math. Download from http://www.whitehousegov/ostp/pcast.

[17] Samson, C., Sullivan, J., Reitsman, R. F. and Soltys, M. (2015). The Relevance of K-12 Engineering Curricula to NGSS: An Analysis of TeachEngineering NGSS Alignment, *Proceedings of 2015 American Society of Engineering Education Annual Conference & Exposition*, Seattle, WA, June.

[18] Capobianco, B. M., Diefes-Dux, H. A., Mena, I. and Weller, J. (2011). What is an Engineer? Implications of Elementary Student Conceptions for Engineering Education. *Journal of Engineering Education*, 100 (2), 304-328.

[19] Wendell, K. B. and Rogers, C. (2013). Engineering Design-Based Science, Science Content Performance, and Science Attitudes in Elementary School. Journal of Engineering Education, 102 (4), 513-540.

[20] Massi, L., Reilly, C., Johnson, D. and Castner, L. (2012). Expanding Your Horizons: The Impact of a One-Day Conference on Middle School Girls' and Parent's Attitudes Toward STEM Careers, *Proceedings of the 2012 American Society of Engineering Education Annual Conference & Exposition*, San Antonio, TX, June.

[21] USNEWS (2015). A look at Minorities in STEM, www.USNEWS.com accessed October 29, 2015.

[22] Blaisdell, S. (2000). “Students’ decision to enter engineering: How men and women differ.” Proceedings of the WEPAN Annual Conference, pp. 243-251.
[23] Jacobs, J. E., Hyatt, S., Osgood, W. D., Eccles, J. S. and Wigfield, A. (2002). Changes in Children’s Self-Competence and Values: Gender and Domain Differences across Grades one through twelve. Child Development, 73 (2), 509-527.
[24] NSF Advance. (2009). Retrieved from http://www.nsf.gov/pubs/2009/nsf0941/nsf0941.pdf August, 2009.
[25] Chopra, S., Bertoline, G. R., and Laux, C., M. (2012). Finding What Women Want: Developing Strategies to Increase Recruitment and Retention of Women. *Proceedings of the 2012 American Society of Engineering Education Annual Conference & Exposition*, San Antonio, TX. June.
[26] Hirsch, L. S., Berliner-Heyman, S., Cano, R., Kimmel, H. and Carpinelli, J. (2011). Middle School Girls’ Perceptions of Engineers Before and After a Female Only Summer Enrichment Program. *Proceedings of* the 2011 ASEE Frontiers in Education Annual Conference, Rapid City, South Dakota, October.
[27] Mehalik, M. M., Doppelt, Y., and Schunn, C. D. (2008). Middle School Science through Design-Based Learning versus Scripted Inquiry: Better Overall Science Concept Learning and Equity Gap Reduction. *Journal of Engineering Education*, 97 (1), 71-85.
[28] Boettcher, B., Carlson, B., Cyr, M. and Shanbhag, S. (2005). Engineering Implementation in Grades 6-12: Evaluation of the Effectiveness of a Workshop Model. Proceedings of the 2005 American Society of Engineering Education Annual Conference & Exposition, Portland, OR, June.
[29] Tran, N. A. and Nathan, M. J. (2010). An Investigation of the Relationship between Pre-College engineering studies and student achievement in Science and Mathematics. Journal of Engineering Education, 99(2), 143-157.
[30] Zarske, M., Sullivan, J., Carlson, L. and Yowell, J. (2004). Teachers Teaching Teachers: Linking K-12 Engineering Curricula with Teacher Professional Development. Proceedings of the 2004 American Society of Engineering Education Annual Conference & Exposition, Salt Lake City, UT, June.
[31] Furner, J. M. and Kumar, D. D. (2007). The Mathematics and Science Integration Argument: A Stand for Teacher Education. Eurasia Journal of Mathematics, Science and Technology Education, 3 (3), 185-189.
[32] NGSS Lead States (2013). *Next Generation Science Standards: For States, By State*. Washington, DC: The National Academies Press. Available at http://www.nextgenscience.org/
[33] Cavanagh, S. (2009, September 8). Panel Wants Engineering Integrated into the Curriculum, Education Week. http://www.edweek.org/ew/articles/2009/09/08/03engineering.h29.html.
[34] Coppola, R.K. and Malyn-Smith, J. (2006). Preparing for the Perfect Storm. Newton, MA: Education Development Center, Inc.
[35] Olds, S., Patel, C., Yalvac, B., Kanter, D. and Goel, N. (2004). Developing a Standards-based K-12 Curricula through Partnerships with University Students and Industry. Proceedings of the 2004 American Society of Engineering Education Annual Conference & Exposition, Salt Lake City, UT.
[36] Widener, A. (2014). A New Standard. *Chemical & Engineering News*, September, 92 (35), 43-45.
[37] Gewertx, C. (2014). Teachers Feel Ill-Prepared for Common-Core Despite Training, *Education Week*, August 20, 2014, 34 (1), pg. 9. http://www.edweek.com/ew/articles/2014/08/20/01teachers.h34.html
[38] Cano, R., Kimmel, H., Koppel, N., and Muldrow, D. (2001). “A First Step for Women into the Engineering Pipeline”. *Proceedings of the 31st ASEE/IEEE Frontiers in Education Conference*, Reno, NV, October 2001.
[39] Koppel, N., Cano, R., Heyman, S. (2002). “An Attractive Engineering Option for Girls” Proceedings of the 32nd ASEE/IEEE Frontiers in Education Conference, Boston, MA, November.
[40] Hofman, H. "Engineering as a career choice: Strengthening the weakest link" *WEPAN National Conference, 2000*. 137-143
[41] Hartman, H. "A gender lens on Rowan University’s College of engineering", *Joint NAMEPA/WEPAN National Conference*, Alexandria, Virginia, Apr. 21-24, 2001.32-38.
[42] National Commission on Mathematics, Science and Technology, (2000). “Before it’s too Late”.
[43] Conlin, M. (2003) The New Gender Gap, Business Week, May 26.
[44] Gibbons, M. (2006). Women in engineering, *ASEE Prism, 15(5)*, January 2006.
[45] Mead, S. (2006). The evidence suggests otherwise: The truth about boys and girls. Education Sector. Retrieved November 2012, from www.educationsector.org
[46] Koppel, N. B., Cano, R. M., Heyman, S. B. and Kimmel, H. (2003). “Single Gender Programs: Do they Make a Difference?” Proceedings of the 33rd *ASEE/IEEE Frontiers in Education Conference*, Boulder, CO, November.
[47] Meyer, P. (2008). Learing separately: The case for single-sex schools. *Education Next, 8(1),* 10-21.
[48] Erling,S. and O’Reilly, J. (2009). Single-Sex Schools: A Review of the Literature, Organizational Development/Research and Information Services, Toronto District School Board.

[49] National Education Association, Research Spotlight on Single-Gender Education. Retrieved December 2013 from www.nea.org
[50] Mael, F. A., Alonso, A., Gibson, D., Rogers, K. and Smith, M. (2005). Single-sex versus co-educational schooling: A systematic review. U.S. Department of Education, Office of Planning Evaluation and Policy Development, Washington, D.C. Document No. 2005-01.
[51] Hart, L. C. (2016). When "separate" may be better: Exploring single-sex learning as a remedy for social anxieties in female middle school students, Middle School Journal, Volume 47(2), pp. 32-40. Published online: 5 Jan 2016.
[52] Sampson, P. M., Gresham, G. J., Leigh, M. and Myers, D. M. (2015). "Middle School Single-Gender Science Classes: Self-Concept and Discourse Analysis," *MLET: The Journal of Middle Level Education in Texas*: 2(1).
[53] Bracy, G. (2006). *Separate but superior? A review of issues and data bearing on single-sex education*. Arizona State University, College of Education, Education Policy Research Unit. Retrieved December 2013, from http://epicpolicy.org/files/EPSL-0611-221-EPRU.pdf
[54] Salomone, R. (2006). Single-sex programs: Resolving the research conundrum. *Teachers College Record, 108(4),* 778-803.
[55] Protheroe, N. (2009). Single-sex classrooms. *Principal,88(5),* 32-35.
[56] Cano, R., Berliner-Heyman, S., Koppel, N., Gibbons, S. and Kimmel, H. and (2004). "Evaluation of Summer Enrichment Programs for Womens' Students", *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*, Salt Lake City, UTAH, June.
[57] Bloom, J., Hirsch, L., Kimmel, H., Rockland, R. (2006). "A Study of the Impact of Enrichment Programs on Girls' Attitudes Towards Engineering". *Proceedings of the 2006 International Conference on Engineering Education*, San Juan, PR, July.
[58] Hirsch, L. S., Carpinelli, J., Kimmel, H., Rockland, R. and Bloom, J. (2007). The Differential Effects of Female Only Vs, Co-Ed Enrichment Programs on Middle School Students' Attitudes Toward Science, Mathematics and Engineering, *Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition*, Honolulu,, HI, June.
[59] Hirsch, L. S., Berliner-Heyman, S., Cano, R., Kimmel, H. and Carpinelli, J. (2011). Middle School Girls' Perceptions of Engineers Before and After a Female Only Summer Enrichment Programg, *Proceedings of the 41st ASEE/IEEE Frontiersin Educationl Conference*, Rapid City, SD., October.
[60] Hirsch, L. S., Berliner-Heyman, S., Cano, R., Carpinelli, J., Kimmel, H. and Romero, S. (2013). A Comparison of Single and Mixed Gender Engineering Enrichment Programs for Elementary Students, *Proceedings of the 43rd ASEE/IEEE Frontiersin Educationl Conference*, Oklahoma City, OK, October.
[61] Hirsch, L. S., Berliner-Heyman, S., Cano, R., Carpinelli, J. and Kimmel, H. (2014). The Effects of Single vs. Mixed Gender Engineering Enrichment Programs on Elementary Students' Perceptions of Engineers, *Proceedings of the 2014 American Society for Engineering Education Annual Conference & Exposition*, Indianapolis, IN, June.
[62] Gibbons, S., J., Hirsch, L., S., Kimmel, H., Rockland, R. and Bloom, J. (2004). "Middle School Students Attitudes to and Knowledge About Engineering". *Proceedings of the 2004 International Conerence on Engineering Education*, Gainesville, FL, October.
[63] Knight, M. and Cunningham, C. M. (2004). "Draw an engineer test (DAET): development of a tool to investigate students' ideas about engineers and engineering". In: *Proceedings of the 2004 ASEE annual conference and exposition*, Salt Lake City, Utah, June.
[64] Karatas, F., Micklos, A., and Bodner, G. (2008). "Sixth Grade Students' Images of Engineering: What do Engineers Do?" *Proceedings of the 2008 American Society for Engineering Education Annual Conference & Exposition*, Pittsburg, PA, June.
[65] Fralick, B., Kearn, J., Thompson, S. and Lyons, J. (2007). "How Middle Schoolers Draw Engineers**,** *Proceedings of the 2007American Society for Engineering Education Annual Conference & Exposition*, Honolulu, Hawaii, June.
[66] Hirsch, L. S., Carpinelli, J. D., Kimmel, H., Rockland, R. and Bloom, J. (2007). "Differential Effects of Pre-engineering Curricula on Middle School Students' Attitudes to and Knowledge of Engineering Careers". *Proceedings of the 37th ASEE/IEEE Frontiers in Education Conference*, Milwaukee, WI, October.
[67] Kimmel, H., Carpinelli, J., Burr-Alexander, L., Hirsch, L. and Rockland, R. "Introducing Robotics into the Secondary Science Classrooms," *Proceedings of the 19th International SITE Conference*, pp. 4189-4194, Las Vegas, NV, March.