A Study of the Impact of Enrichment Programs on Girls' Attitudes Toward Engineering

Linda S. Hirsch [1], Howard Kimmel[2], Ronald Rockland[3], and Joel Bloom[4]

***Abstract* – Most young girls do not know much about engineering and as a result do not explore engineering as a career option. The Woman in Engineering and Technology program is designed to expose young girls to careers in engineering and improve the academic skills required to study engineering in an effort to increase the number of women pursuing careers in engineering. Attitudes toward engineering are an important predictor of whether students pursue an engineering career. Because boys and girls do not differ in technical abilities until the later high school years but rather in their attitudes toward technological careers including engineering, programs that begin in middle school can be instrumental in informing young girls and changing their attitudes. The Middle School Students' Attitude to Engineering, Science and Mathematics Survey has been given to girls attending the Woman in Engineering and Technology program over the last few years. Compared to other middle school students of similar background girls in the program have more positive attitudes to engineering, science and mathematics, more knowledge of engineering careers and higher self-efficacy for engineering skills.**

Index Terms – Girls' attitudes to engineering and knowledge about engineering careers, enrichment programs for girls, single gender programs.

The demand for more engineers in our workforce is expected to increase faster than for any other occupation by the year 2010 [1] but the number of students studying engineering has changed very little in the last decade [2]. In fact the number of students completing engineering degrees in New Jersey has decreased [3]. Furthermore, women are chronically under-represented: Less than 10% of engineers in the United States are women [4], a proportion that does not appear to be changing [3].

On a nationwide survey of college-bound high school students taking the PSAT during the 2002-2003 academic year only 16% of the male students and 2% of the female students indicated they intended to study engineering in college [5]. These figures are even lower for New Jersey.

A students' choice of career is influenced by their ability to assess their own skills and interests and relate them to the needs of the current and future workforce. One of the reasons more students do not choose engineering as a career is lack of academic preparation in high school. Another reason is that they simply do not know what engineering is or what engineers do. Unlike doctors, lawyers and even firemen, engineers are rarely depicted in television shows and movies. And students are often not able to discuss engineering as a possible career with their parents, teachers and school counselors because they also do not know much about engineering.

Although being uniformed and a lack of academic preparation in high school, especially in science and math are the most crucial reasons for why students' do not pursue careers in engineering [6] even those students who are adequately prepared and initially choose engineering often do not persist. Students' interest, their attitudes toward engineering and their opinions about engineers upon arrival in college are also important predictors of persistence in engineering. Studies of students who dropped out of engineering programs indicate that while inadequate preparation and grades are important they only partially explain why students quit engineering. Many students quit in good standing with grades similar to those that stayed, but were less interested, had significantly poorer attitudes to engineering, lower general impressions of engineering and less positive perceptions of the work engineers do [7]-[15].

Therefore, in addition to being better prepared in math and science potential college students need to be more well-informed about engineers and engineering and have more positive attitudes toward engineering not just so more students choose to study engineering but so more students succeed in engineering.

During elementary school boys and girls are relatively equal in ability; not until the middle school years do girls' attitudes start to change [16]. Girls begin to underestimate their own technical abilities; in high school they enroll in fewer high level mathematics and science courses and as a result enter college without the prerequisites necessary to enroll in high tech majors such as engineering [17] [18].

[1] Linda S. Hirsch, Program Evaluator, Center for Pre-college Programs, New Jersey Institute of Technology, lhirsch@adm.njit.edu
[2] Howard Kimmel, Executive Director, Center for Pre-college Programs, New Jersey Institute of Technology, kimmel@adm.njit.edu
[3] Ronald Rockland, Associate Dean of Engineering, New Jersey Institute of Technology, rockland@adm.njit.edu
[4] Joel Bloom, Vice-President for Academic and Student Services, New Jersey Institute of Technology, bloom@adm.njit.edu

Early intervention is needed to prevent this from happening as it is hard to correct once girls reach college [19].

Many students, particularly girls, develop negative impressions about engineering work conditions that prevent them from seriously considering engineering careers. For example, they may not see themselves as fitting the profile of the typical engineer (i.e. they are not a genius) or may fear that the engineering environment will not be welcoming [20]. Women were more likely to choose majors and careers in which their sex is adequately represented because they perceived less discrimination and greater opportunity for achievement [21]. Often women believe that engineering is incompatible with family life or that the monetary rewards are not worth the effort involved [16], [22].

Women also tend to be attracted to professions that contribute to society such as medicine, dentistry and law and there has been a significant increase in women entering these fields [23]. Almost half of our nation's law students are women. Biomedical engineering is defined as applying traditional engineering expertise to analyze and solve problems in biology and medicine, providing an overall enhancement of health care and appears to appeal to women, since biomedical engineering is one of the few engineering fields that have a large proportion of female students. While only about 20% of bachelor's degrees in engineering have gone to women over the past five years, women earned almost 46% percent of the bachelor's degrees in biomedical engineering [24].

The differential interest between biomedical engineering and other engineering fields is probably due to students easily recognizing that medicine and other health related fields can help people which they are not necessarily able to do in other fields. If more women are to pursue careers in all engineering fields misinformation and negative impressions about engineers and the field of engineering must be eliminated [4]. Young girls should be introduced to women who have succeeded in engineering. Research indicated that many students who choose to study engineering have influential role models [25] and girls who become engineers often have fathers who are engineers [26]. And while engineering is still a male dominated field, young women should know that sex discrimination in engineering wages in the US has almost been eliminated. Salaries of men and women engineers with the same years of experience are virtually equal with women earning 97 cents for every dollar men earn [27].

WOMEN IN ENGINEERING AND TECHNOLOGY PROGRAM

The Center for Pre-College Programs at New Jersey Institute of Technology (NJIT) offers a Woman in Engineering and Technology program (FEMME) designed to improve the science, mathematics and technology skills of young women in an effort to increase the number of women interested in engineering and other technological careers. The FEMME program spans grades four to eight because the middle school years have been found to be such an important time for all students to begin thinking about future careers. Although there is some debate about the overall effectiveness of single gender educational environments [23] research has shown that girls appear to be more comfortable contributing to classroom discussions, asking questions, and participating in activities; and develop more positive attitudes toward mathematics and science in single gender environments.

Originally established in 1981 as a year long program for ninth grade girls, [18] the FEMME program was expanded in 1993 to include post 4th and 5th grade girls, and by 1999 included girls in grades 6, 7 and 8. Currently, FEMME is an intensive four-week summer program for post-fourth to post-eighth girls designed to 1) enhance their science and mathematics achievement, 2) develop their critical thinking and problem solving skills, 3) increase their interest in engineering and other high tech fields and 4) motivate them to take advanced placement science and mathematics courses in high school. In addition to classroom learning and laboratory experiments the girls participate in counseling sessions and go on field trips. The girls are introduced to female engineers and have the opportunity to see first hand the career options available to them. The academic curriculum for each FEMME group is grade appropriate and aligned with New Jersey Core Curriculum standards but the focus of each group is different. For example, the post fourth-graders (FEMME4) focus on Environmental Science, FEMME5: Aerospace Engineering, FEMME6; Mechanical Engineering, FEMME7; Chemical Engineering, and FEMME8; Biomedical Engineering.

EVALUATIONS

Initial evaluations of the FEMME program have been positive but primarily formative in nature [28]. Girls participating in FEMME programs in the past few years have been found to have positive attitudes toward engineering. Follow-up studies of program participants who had completed high school found exceedingly high proportions (over 60%) reporting that they were either currently enrolled in a technology based degree program or had chosen a career path in engineering, mathematics, science or computer technology [19], [28].

SURVEY TO MEASURE ATTITUDES TO ENGINEERING, SCIENCE AND MATHEMATICS

During the summers of 2003 and 2005 girls in the FEMME programs completed the Middle School Attitude to Engineering, Science and Mathematics Survey. The survey was developed at the Center for Pre-College Programs at NJIT as part of the Pre-Engineering Instructional and Outreach Program (Pre-IOP); a three-year project funded by the New Jersey Commission on Higher Education. The

objective of the program was to increase the number of students, particularly those from groups traditionally underrepresented in engineering, particularly women, who enroll in engineering schools in New Jersey in part by informing students, their teachers, parents, and school counselors about the rewards of a career in engineering. Different versions of the survey have been developed for teachers, parents, middle school students, high school students and school counselors. The parent and high school versions have been translated into Spanish since many of the students in our programs are of Hispanic decent. For details on the development of the surveys and their psychometric properties see [29]-[31].

For the current paper the Middle School Attitude to Engineering, Science and Mathematics Survey was used to measures students':

- **Attitudes to Engineering, Science and Mathematics:** Students indicate the degree to which they agree or disagree with statements about science, mathematics, engineering and the kinds of things that engineers do such as "engineers help make peoples lives better" on a five-point scale where 1 indicates strong disagreement and 5 indicates strong agreement. A sixth point, scored as zero (0), allows students to indicate they "do not know".
- **Knowledge of Engineering Careers:** A multi-part open-ended question asks students to "Name five different types of engineers" and to "give an example of the work done by each type". Each type 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 current paper is a summary of the results of the survey completed by girls in the 2003 and 2005 FEMME programs. Results are compared to those from other middle school girls and boys of similar background during the same time periods to determine if the girls in the FEMME program have more positive attitudes to engineering, science and mathematics and more knowledge of engineering careers.

RESULTS

One hundred seventy eight (178) girls in the FEMME programs took the Middle School Attitude to Engineering, Science and Mathematics Survey during the summers of 2003 and 2005. During the same time period's 111 boys and 124 girls from similar backgrounds (including some of the same schools) also took the survey (Comparison students). See Table I for a summary of the demographic characteristics.

TABLE I
DEMOGRAPHICS OF FEMME AND COMPARISON GROUP STUDENTS

	FEMME GIRLS	COMPARISON STUDENTS
GRADE		
4TH	11%	0%
5TH	12%	18%
6TH	18%	17%
7TH	28%	32%
8TH	31%	33%
ETHNICITY		
African American	34%	33%
Hispanic\Latino	44%	19%
Caucasian	9%	31%
Asian	5%	7%
Biracial	5%	5%
Other	3%	5%

Attitudes to Mathematics, Science and Engineering

Psychometric analyses identified seven subscales within the Attitude to Mathematics, Science and Engineering Scale [32]; Interest in engineering: stereotypic aspects (Stereotypic), Interest in engineering: non-stereotypic aspects (Nonstereotypic), Negative opinions of mathematics & science (Negative), Positive opinions of mathematics and science (Positive), Problem Solving (Problems), Technical Skills (Technical) and a general subscale. See Table III for items on each subscale.

The average response to all items on the Attitudes to Mathematics, Science and Engineering Scale for the FEMME girls was 3.3 compared to 3.1 for the comparison students. Higher averages (close to 5) on the subscales that emphasize positive aspects of engineering (Stereotypic, Nonstereotypic, Positive, Problems, and Technical) are desirable while a lower average (close to 1) is desirable for the Negative subscale. For the Total scale, negatively stated items have been reversed so that higher average scores indicate more positive attitudes. Significant differences were found between the FEMME girls and the comparison students on Total scale and all of the subscales indicating that the girls in the FEMME program had significantly more positive attitudes toward mathematic, science and engineering (see table II).

TABLE II
MEANS AND STANDARD DEVIATIONS FOR THE ATTITUDES TO MATHEMATICS, SCIENCE AND ENGINEERING SCALE AND SUBSCALES

	FEMME Mean (SD)	COMPARISON Mean (SD)	p-value
Total Scale	3.3 (.3)	3.1 (.3)	<.01
Subscales			
Stereotypic	3.5 (.5)	3.3 (.6)	<.01
Non-stereotypic	3.3 (.6)	3.1 (.7)	<.01
Positive	3.6 (.5)	3.3 (.7)	<.01
Negative*	2.7 (.6)	2.9 (.5)	<.01
Problems	3.1 (.7)	3.0 (.7)	<.05
Technical	4.0 (.6)	3.1 (.7)	<.001
General	3.4 (.5)	3.1 (.6)	<.01

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

To examine differences between the FEMME students' responses to the individual items on the Attitude to Mathematics, Science and Engineering Scale and the comparison students' responses the percentage of agree and strongly agree responses were combined into "% Agree", the percentage of disagree and strongly disagree responses were combined into "% Disagree" and the percentage of I don't know and No opinion responses were combined into "% Don't Know" (see Table III).

Significant differences were found between the FEMME girls and the comparison students on all but three items: When I grow up I would like to build computers; It scares me to have to take math classes; and People would look up to me if I had a job in science or math. The interesting differences are in the percentages of I don't know responses. For example 77% of the FEMME girls agreed they would like to be an engineer when they grow up compared to 66% of the comparison students which is not necessarily overwhelming but only 8% of the FEMME girls indicated they did not know compared to 22% of the comparison students. And only 5% of the FEMME girls indicated they did not know if engineers help make people's lives better compared to 17% of the comparison students. Apparently the comparison students don't just have significantly lower attitudes toward mathematics, science and engineering they appear to be significantly less informed.

TABLE 1II
GROUP DIFFERENCES IN RESPONSE TO ITEMS ON THE ATTITUDES TO MATHEMATICS, SCIENCE AND ENGINEERING SURVEY

	% Agree		% Disagree		% Don't Know	
	FEMME	OTHERS	FEMME	OTHERS	FEMME	OTHERS
Interest: stereotypic aspects						
I would like a job where I could invent things	65	53	25	25	10	25
I would like to be an engineer when I grow up	77	66	15	12	8	22
I think I am good at technical things	58	29	20	28	21	43
When I grow up I would like to build computers*	4	5	94	89	2	7
I would like to help plan bridges, skyscrapers and tunnels	96	84	3	7	1	9
I would like a job that lets me build robots	68	59	20	18	12	23
I would like a job that lets me design cars	76	48	13	18	10	34
Interest: non-stereotypic aspects						
I would like a job helping make new medicines	3	9	95	78	1	13
I would like to build & test machines that could help people walk	79	59	6	14	15	28
I would like a job in which I could help protect the environment	68	54	18	16	14	30
I would like a job designing clothes to be worn in outer space	39	47	43	28	18	25
Positive opinions						
I think that having a job in science or math would be fun	73	39	17	31	10	30
I would like to study science\math because I could make more money	78	64	14	14	9	22
I would like a job that lets me do a lot of math and science	63	41	21	30	15	29
People would look up to me if I had a job in science or math*	43	39	42	41	14	20
Negative opinions						
It scares me to have to take math classes*	95	90	1	5	3	5
Math & science have nothing to do with real life	32	37	66	45	2	18
People who do lots of science & math are boring	53	22	21	41	26	37
Only nerds spend lots of time doing math and science	89	81	9	7	2	12
It makes me nervous to even think about doing science	5	9	93	77	2	14
To be good at math or science you have to be very smart	66	47	18	16	16	37
Kids who do science & math spend little time with other kids	6	6	92	80	2	14
Problem Solving						
I am good at solving word problems in math	5	12	88	64	7	24
I think I could do well in an advanced math or science class	83	61	3	9	14	30
I am good at problems that can be solved in many different ways	48	33	41	37	11	30
To get a job doing math\science you have to be good at solving problems	41	21	44	48	15	31
Technical Skills						
I like knowing how things work	70	45	22	27	8	28
I am good at putting things together	88	71	4	9	8	20
I would like a job that lets me figure out how things work	83	63	14	18	3	19
I like thinking of new and better ways of doing things	63	43	22	23	16	34
General						
When I am old enough I will go to college	80	63	9	12	11	25
Scientists help make people's lives better	83	72	9	10	8	18
I think I know what engineers do	93	81	5	4	2	15
Engineers help make people's lives better	20	2	75	81	5	17
I would like a job that lets me spend time working on computers	21	22	63	49	16	30

* Due to rounding the percentages for each item may not sum to exactly 100.

Knowledge of Engineering Careers

The Knowledge about Engineering and Engineering Careers measure is a two-part, open-ended question. Students are asked to name five different types of engineers and to give an example of the work each type of engineer does. Space is provided to list five types of engineers and an example of work done by each type of engineer. Responses to the first part "Name a type of engineer" were coded as incorrect and given a score of "0" (zero) or correct and given a score of "1" (one) according to the protocol developed for the High School version of the survey [10]. Possible total scores range from zero to five. Correct responses to the second part "Give an example of the work they do" are not as easily scored as responses to the first part. Responses can show some understanding of what a particular type of engineer does without being completely correct, yet the response is not necessarily incorrect. Therefore, answers to the second part of the question were coded as incorrect and given a score of "0" (zero), partly correct and given a score of "1" (one), or correct and given a score of "2" (two). Possible total scores range from zero to ten.

Significant differences in the responses to both parts of the Knowledge of Engineering Careers question were found. Distributions of scores for each part of the question are not normally distributed so it was not possible to calculate mean numbers of correct responses for either part of the question. Chi-Square Tests of Independence were used to compare the distributions of scores for the FEMME girls to the distributions of scores for the comparison students.

Only 3% of the comparison students were able to "Name five Different Types of Engineers" compared to 33% of the FEMME girls. Fifty-four percent of the comparison students were not able to correctly name even one type of engineer compared to only 16% of the FEMME girls (X^2_5 = 126.6, p<.001). See Table IV for a complete summary of all responses.

TABLE IV
STUDENTS RESPONSES TO KNOWLEDGE OF ENGINEERING QUESTION, PART 1, NAME FIVE DIFFERENT TYPES OF ENGINEERS.

	Number Correct Responses					
	0	1	2	3	4	5
FEMME girls	16%	10%	15%	13%	13%	33%
Comparison students	54%	24%	9%	5%	6%	3%

None of the students in either group were able to give five completely correct examples of the kind of work each type of engineer does; the highest score for this part of the knowledge question was 9: But only a very few in each group scored more than 6 points. Sixty-three percent of the comparison students were not able to give any correct examples of the type of done by each type of engineer they named compared to only 35% of the FEMME girls (X^2_6 = 41.6, p<.001). See Table V for a complete summary of all responses.

TABLE V
STUDENTS RESPONSES TO KNOWLEDGE OF ENGINEERING QUESTION, PART 2, GIVE AN EXAMPLE OF THE WORK DONE BY EACH TYPE.

	Number Correct Responses						
	0	1	2	3	4	5	6+
FEMME girls	35%	21%	18%	7%	6%	7%	6%
Comparison students	63%	12%	15%	4%	3%	1%	3%

DISCUSSION

The current sample of girls from the FEMME program is not necessarily representative of middle school girls in New Jersey rather they represent the effectiveness of an enrichment program designed to increase middle school girls attitudes toward engineering and other technology occupations in an effort to increase the number of young girls who choose to pursue high-tech careers. They had significantly more positive attitudes toward engineering and had significantly more knowledge of engineering careers compared to other male and female students from similar backgrounds. More research is needed to investigate exactly which aspects of the FEMME program may be responsible for the differences but the current study is a first step in establishing the effectiveness of the program.

When young girls are exposed to women in engineering and have the opportunity to explore first hand the kinds of things engineers do they develop more positive attitudes toward engineers and engineering and appear to be more knowledgeable about different types of engineers and what they actually do.

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