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FEMMES: A ONE-DAY MENTORSHIP PROGRAM TO ENGAGE 4TH–6TH GRADE GIRLS IN STEM ACTIVITIES

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Existing gender disparities in science, technology, engineering, and math (STEM) fields underscore the need for outreach programs to engage young women in these subjects. Although many programs exist for high school students, girls may lose interest in STEM subjects at an earlier age. Females Excelling More in Math, Engineering, and Science (FEMMES) hosts an annual, free, one-day event that provides exciting, hands-on workshops for 4th–6th grade girls from Durham, North Carolina, to encourage them to further explore their potential in these fields. This study evaluated the effect of the one-day event ("Capstone") on the 4th–6th grade girls' interest in, knowledge of, and confidence in STEM subjects. Assessments (self-reported ratings) were obtained from 319 participants prior to, immediately after, and again three months after the Capstone event. A repeated measure ANOVA (analysis of variance between groups) revealed a significant increase in interest in engineering, and confidence and knowledge of math, science, and engineering three months after the one-day event. Continued exposure to STEM fields through outreach programs like the FEMMES semester-long afterschool program (Chen et al., J. Women Minor. Sci. Eng., vol. 17, no. 4, p. 315–327, 2011; companion paper) may result in stronger long-term outcomes. Results from this study indicate that hands-on workshops and mentorship from female faculty, graduate students, and undergraduate students may be important factors in inspiring young girls to pursue STEM fields.

KEY WORDS: *education, outreach, hands-on, underprivileged, elementary school, middle school, gender disparity, interest, confidence, knowledge*

1. INTRODUCTION

For many generations females have been especially underrepresented in science, technology, engineering, and mathematics (STEM). Although efforts over the past few decades have been dedicated to understanding the gender gap in STEM fields (Clewell and Campbell, 2002; Gilbert and Calvert, 2003), inequalities still exist. Even within the sciences, Farenga and Joyce (1999) have shown that young students, as early as at the elementary level, perceive certain subjects within those fields as more masculine (e.g., physical sciences) or more feminine (e.g., life sciences).

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Thus many research and educational imperatives have focused on approaches and strategies to improve girls' attitudes toward STEM fields (Brotman and Moore, 2007; Demetry *et al.*, 2009; Fadigan and Hammrich, 2004; Heller and Martin, 1994).

Based on extensive research, girls seem to benefit from inquiry-based learning and hands-on lab activities (Burkam *et al.*, 1997; Cavallo and Laubach, 2001; Kahle and Damnjanovic, 1994; Lee and Burkam, 1996). For example, Kahle and Damnjanovic (1994) assessed girls' attitudes toward physical science through inquiry-based activities that combined laboratory exercises and peer discussions. They found a significant increase in girls' enjoyment and interest in electricity topics after completing the hands-on activities as compared to a self-reported preassessment. However, the efficacy of hands-on science activities for girls may be diminished when these methods are implemented in classrooms where both genders are present. Jovanovic and King (1998) showed that when both genders were participating in the same activities, girls and boys did not partake in hands-on activities equally. Boys would tend to dominate in handling the equipment and resources. Thus, in a cogender classroom setting, girls might not benefit from hands-on experiences to the same degree as boys.

By establishing extracurricular programs focused primarily on young females, some of the issues regarding male superiority in the science classrooms might be eliminated. In many studies, researchers have found that exposure to STEM fields through educational outreach programs for girls starting at the elementary school level have increased girls' interest and confidence in STEM fields; this is especially evident in their choices of science- and math-heavy coursework later in high school (Demetry *et al.*, 2009; Fadigan and Hammrich, 2004). While boys are more likely to engage in hands-on activities, similar to lab exercises outside of school, girls are less likely to seek these opportunities (Lee and Burkam, 1996). Outreach programs targeting girls would provide increased exposure in the sciences in a setting where they are not overshadowed by their male peers. Because an individual's confidence and motivation to achieve in a given field is highly correlated with her/his level of self-efficacy and expectation of success in that field (Bandura, 1997; Eccles *et al.*, 1985; Leslie *et al.*, 1998), having female faculty and mentors in STEM fields act as role models in these programs will positively affect girls' attitudes toward STEM careers (Smith and Erb, 1986). In addition, surrounding girls with a wide spectrum of female role models, from accomplished faculty members to graduate and undergraduate students in STEM fields (Demetry *et al.*, 2009), may give the girls a more profound sense of self-confidence in the sciences.

While some STEM outreach programs involving hands-on learning do reach out to females, they do not all serve underprivileged communities. Some programs may require tuition or "cut-off" test scores or school recommendations that may pose an obstacle for students in such communities. Durham is an underserved district in North Carolina where many students face socioeconomic challenges. The North Carolina School Report Cards from 2008–2009 show 48.9% of 5th graders from Durham public schools scoring at or above grade level on end-of-grade science tests for the No Child Left Behind Act (NC School Report Cards, 2009a). This percentage is less than scores reported from the nearby school district of Chapel Hill-Carrboro (85.2%) and is also below the state average of 60.8% (NC School Report Cards, 2009b). Durham public schools may not have as many resources as do private or public schools in more affluent communities. As a result, female students with potential to succeed in STEM disciplines may not have a fair amount of opportunities to explore their potential. The Females Excelling More in Math, Engineering, and Science (FEMMES) organization, established in 2006 at Duke University, caters to the need for hands-on outreach programs in the Durham community to enrich girls' interests in STEM fields.

1.2 Overview of the FEMMES Capstone Event

FEMMES is a student-run organization established in 2006 at Duke University in Durham, North Carolina. FEMMES offers an annual, cost-free, one-day Capstone event for over two hundred 4th–6th grade female students from Durham elementary schools. The students come to Duke University on the day of the event to participate in science, math, and engineering activities. The students are divided into groups of 14–16, each led by 2–3 Duke student female counselors. The day opens with a keynote speech, followed by two interactive faculty-led activities, a free lunch, and ends with two additional interactive faculty-led activities. The schedule of the day's events from the 2009 FEMMES Capstone event is summarized in Appendix A. The activities are held in science and engineering facilities on Duke's campus and last 45 minutes each. Activity subjects, determined by the expertise of the female faculty who lead them, include topics such as chemistry, neuroscience, genetics, pharmacology, computer programming, and biomedical and electrical engineering (see Appendix B).

2. METHODS

2.1 Participants

2.1.1 The Girls

The participants include 4th–6th grade female students in the Durham, North Carolina, area attending public or private schools. Approximately 200 students sign up to attend the FEMMES Capstone event each year.

2.1.2 The Undergraduate and Graduate Student Volunteers

Undergraduate and graduate volunteers are Duke students majoring in or interested in math, science, and engineering fields. Two to three volunteers lead a group of participants throughout the entire day. This mentorship opportunity provides the participants with positive female role models, maximizes learning, and creates a comfortable atmosphere for the participants.

2.1.3 The Faculty Volunteers

Faculty volunteers are female Duke professors in science, math, and engineering fields. They design their own activities and lead each activity with the help of female graduate student and postdoctoral fellow volunteers. As role models and experts in their field, faculty members and their assistants demonstrate that women can and do excel in STEM fields.

2.2 Recruitment

Participants were recruited in five ways and then enrolled in the order that their registration packets are received.

1. Registration packets are given to the senior educational partnership coordinator for the Duke-Durham Neighborhood Partnership. He distributes the registration packets to the Durham community and to Durham Public Schools.
2. Registration packets are emailed to previously established contacts at various community centers and Durham schools.
3. Registration packets are emailed to parents of students who have participated in the FEMMES program in the past.

4. FEMMES program directors go to a few Durham schools to hand-distribute the registration packets.
5. Registration packets are available on the FEMMES website.

2.3 Capstone Features

There are several features that comprise the Capstone day. These components all create opportunities for the girls to interact with and learn from the faculty volunteers and the student volunteers.

2.3.1 Keynote Speaker

The keynote speaker is a female faculty member from a science, math, or engineering field. For 30 minutes she talks to the girls about her field of interest, how she got there, obstacles she faced, and how the girls can pursue their interests. The keynote speaker then answers any questions the girls may have.

2.3.2 Lab Activities

Girls and their student volunteers attend a total of four activities over the course of the day. Below is a table of sample activities from each subject (Table 1). A complete list and description of activities can be found in Appendix C.

TABLE 1: Sample activity from each subject area represented at the capstone event

Subject	Activity name
Biology	It's in Our Genes
Engineering	Tales of H_2O
Chemistry	Oxygen can be Hazardous to Your Health!
Pharmacology	Pharmacologists as Sleuths
Computer Science	Creating a 3D Interactive Story
Mathematics	Games, Probability, and Patterns
Environmental Science	Chemistry of the Earth
Statistics	Statistics for Better Decisions

2.4 Program Assessment

To assess the effectiveness of the FEMMES Capstone event and its impact on the grade school student participants, surveys were completed by participants before, on the day of, and three months after the 2008 and 2009 events (referred to as pre-, post-, and follow-up, respectively). The research protocol was approved by Duke University's Institutional Review Board (IRB), and parental consent was obtained. The three surveys were encoded with a number to protect confidentiality. The pre-survey was given to the participants as part of the registration packet, approximately two months before the event. The post-survey was administered to the participants at the end of the day of the event. The follow-up survey was mailed to the participants' homes approximately three months after the event with a stamped and addressed return envelope included. Each participant assessed her own interest, knowledge, and confidence in math, science, and engineering on a scale of 1 to 10 (1 = weakest, 10 = strongest) on the pre-survey, post-survey, and follow-up survey. In addition to the aforementioned items, the post-survey and follow-up survey contained other questions to assess the effectiveness of the event. Sample questions from the surveys are shown below (Table 2), and the complete surveys can be found in the Appendix.

TABLE 2: Sample questions from pre-survey and post- and follow-up surveys

1. Overall, on a scale of 1–10 (10 being very interested, 1 being not interested at all), how interested are you in math?									
1	2	3	4	5	6	7	8	9	10
2. Overall, on a scale of 1–10 (10 being very interested, 1 being not interested at all), how good are you at science?									
1	2	3	4	5	6	7	8	9	10
3. Overall, on a scale of 1–10 (10 being very interested, 1 being not interested at all), how much do you know about engineering?									
1	2	3	4	5	6	7	8	9	10

2.5 Data Analysis

Responses from the pre-, post-, and follow-up surveys were used to assess the level of change in interest, confidence, and knowledge in each of the STEM subject areas, math, science, and engineering. Data collected from a total of 319 respondents during both 2008 and 2009 were combined for the analysis, unless otherwise noted. Only participants who returned all three surveys were analyzed. The mean participant rating and standard deviation for each category were calculated. Repeated measure ANOVAs (analysis of variance between groups) were conducted to detect differences in ratings provided in the pre-, post-, and follow-up surveys in measures of self-perceived interest, confidence, and knowledge in each of the STEM subjects. When main effects were significant, post hoc tests were performed for specific pairwise comparisons, adjusted with least significant difference for multiple comparisons.

A subset of students participated in the Capstone event two years in a row (2008 and 2009). To analyze a change in interest, confidence, and knowledge in STEM subjects, a repeated measures ANOVA followed by pairwise comparisons were performed with responses from students who participated in the FEMMES Capstone event for two consecutive years (Fig. 1). To analyze mean participant ratings collapsed across pre-, post-, and follow-up surveys for each grade cohort, a mixed ANOVA followed by a Scheffe's test were performed. Lastly, using responses on the post-survey, the median participant ratings for each faculty-led activity held in both consecutive years were calculated to determine the enjoyment of the activities. All statistical analyses were performed using the statistics program SPSS for Windows (SPSS, Inc., 2008).

3. RESULTS

3.1 Impact of the FEMMES Capstone Event on Interest, Confidence, and Knowledge of STEM Subjects

Overall, the survey results demonstrated that the FEMMES Capstone event improved the participants' attitudes toward STEM subjects. Mean responses of female participants for self-perceived interest, confidence, and knowledge of math, science, and engineering on pre-, post-, and follow-

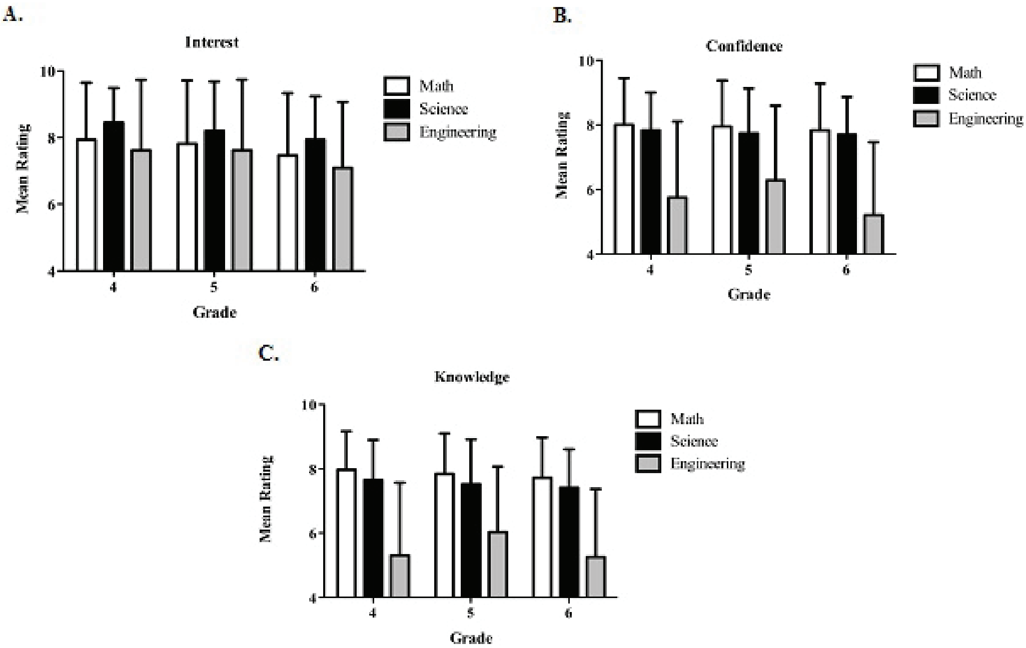

FIG 1: Mean participant ratings by students in grades 4–6 for interest in science, interest in engineering, and confidence in engineering. Participants' mean ratings ± SD (from all surveys) are hown for (A) interest, (B) confidence, and (C) knowledge in the three STEM areas. Ratings are included for all participants (N = 319).

up surveys are summarized in Table 3 (N = 124–138). Significant main effects (either linear or quadratic) were found by repeated measures ANOVA for all measures with the exception of one marginally significant main effect (quadratic) on interest in math [$F(1,135) = 2.881$, $p = 0.092$]. Following the ANOVA, pairwise comparisons were made for all measures. There was a significant increase in participant ratings in interest, confidence, and knowledge from pre-survey to post-survey for all three subject areas (Table 3). Students also reported significantly greater confidence and knowledge in all three subject areas and in interest in science in the follow-up survey compared to the pre-survey. In a few cases, there was a significant decrease in ratings that occurred between the post-survey and the follow-up survey three months later; this decrease occurred in interest in science and interest in engineering.

3.2 Self-Reported Attitudes Based on Grade Level

To examine whether self-perceived ratings differed depending on the grade of the participants, analysis using a series of mixed ANOVAs (with repeated measures) was used. A significant main effect of grade was found on interest in science and engineering and on confidence in engineering (Table 4). Further post hoc analyses revealed that interest in science and engineering and confidence in engineering all declined as the girls got older (see Table 5 for the mean participant ratings in each grade at each survey time). More specifically, 6th-grade girls reported lower ratings for their interest in science and engineering compared to their 4th-grade counterparts. In addition, 6th-grade girls reported less confidence in engineering compared to 5th-grade girls.

TABLE 3: Change in interest, confidence, and knowledge in STEM subjects

Assessment	Subject	*N*	Mean (SD) Ratings			*F(df)*	*P*
			Pre-	Post-	Follow-up		
Interest	Math*	136	7.54 (2.36)	7.95 (2.17)	7.83 (2.16)	2.88 (1135)	0.092
	Science*‡	138	8.06 (1.62)	8.63 (1.49)	8.16 (1.60)	18.36 (1137)	0.000
	Engineering*†‡	132	7.08 (2.50)	8.20 (2.09)	7.48 (2.46)	25.84 (1131)	0.000
Confidence	Math*†	135	7.92 (1.76)	8.22 (1.51)	8.27 (1.47)	4.91 (1134)	0.028
	Science*†	130	7.62 (1.57)	8.08 (1.40)	7.94 (1.23)	19.51 (1134)	0.000
	Engineering*†	124	5.13 (2.80)	6.80 (2.69)	6.37 (2.75)	21.45 (1131)	0.000
Knowledge	Math*†	135	7.74 (1.60)	8.13 (1.39)	8.03 (1.51)	23.53 (1123)	0.000
	Science*†	135	7.26 (1.54)	7.80 (1.57)	7.84 (1.46)	5.96 (1129)	0.016
	Engineering*†	132	4.70 (2.59)	6.29 (2.60)	5.98 (2.66)	6.41 (1134)	0.013

Following repeated measures ANOVAs, pairwise comparisons were performed to identify significant differences between survey times. Data for comparisons include the subset of individuals who filled out all three surveys. *$p < 0.05$, pre- versus post-surveys; †$p < 0.05$, pre- versus follow-up surveys; ‡$p < 0.05$, post- versus follow-up surveys.

TABLE 4: Main effects of grade

Assessment	Subject	*F*	*df1*	*df2*	*P*
Interest	Math	2.58	2	128	0.08
	Science	3.73	2	130	0.027
	Engineering	3.95	2	124	0.022
Confidence	Math	1.41	2	127	0.25
	Science	0.92	2	122	0.40
	Engineering	3.53	2	116	0.033
Knowledge	Math	0.099	2	127	0.91
	Science	1.63	2	127	0.20
	Engineering	2.12	2	124	0.13

Mixed ANOVAs were performed to determine the main effects of grade on interest, confidence, and knowledge in math, science, and engineering. Data for comparisons include the subset of individuals who filled out all three surveys.

3.3 Participant Activity Ratings

Students indicated a high degree of satisfaction with individual activities. The median participant ratings on post-surveys for faculty-led activities are shown in Table 6. Eight out of twenty-one activities were scored with a median rating of 10, the highest possible rating.

TABLE 5: Levels of interest, confidence, and knowledge in STEM subjects by grade

Assessment	Subject	Grade	*N*	Mean (SD) ratings		
				Pre-	Post-	Follow-up
Interest	Math	4	61	7.84 (2.04)	8.17 (1.88)	8.16 (1.76)
		5	43	7.56 (2.59)	7.95 (2.15)	7.84 (2.29)
		6	30	6.92 (2.57)	7.40 (2.72)	7.05 (2.58)
	Science*	4	61	8.23 (1.43)	8.86 (1.18)	8.40 (1.51)
		5	44	8.20 (1.55)	8.53 (1.87)	8.33 (1.71)
		6	31	7.60 (2.00)	8.26 (1.43)	7.39 (1.47)
	Engineering*†	4	57	7.14 (2.57)	8.40 (1.93)	7.88 (2.31)
		5	43	7.42 (2.40)	8.49 (2.07)	7.81 (2.56)
		6	30	6.57 (2.51)	7.40 (2.26)	6.13 (2.20)
Confidence	Math	4	60	8.28 (1.59)	8.24 (1.44)	8.50 (1.15)
		5	43	7.66 (1.90)	8.41 (1.31)	8.27 (1.57)
		6	30	7.65 (1.77)	7.90 (1.90)	7.78 (1.82)
	Science	4	57	7.91 (1.47)	8.15 (1.33)	8.01 (1.31)
		5	41	7.33 (1.75)	8.16 (1.42)	8.00 (1.15)
		6	30	7.57 (1.43)	7.90 (1.44)	7.65 (1.19)
	Engineering†	4	55	5.13 (3.01)	6.95 (2.59)	6.67 (2.52)
		5	38	5.72 (2.56)	7.38 (2.52)	6.84 (2.48)
		6	29	4.43 (2.58)	5.84 (2.84)	5.07 (3.18)
Knowledge	Math	4	59	8.05 (1.29)	8.33 (1.25)	8.27 (1.40)
		5	43	7.57 (1.91)	8.19 (1.40)	7.91 (1.53)
		6	31	7.45 (1.59)	7.60 (1.54)	7.69 (1.67)
	Science	4	60	7.45 (1.37)	8.10 (1.38)	7.95 (1.50)
		5	43	7.12 (1.87)	7.76 (1.73)	7.94 (1.43)
		6	30	7.17 (1.37)	7.25 (1.63)	7.41 (1.40)
	Engineering	4	57	4.53 (2.75)	6.52 (2.61)	6.33 (2.59)
		5	43	5.15 (2.53)	6.62 (2.54)	6.15 (2.59)
		6	30	4.50 (2.33)	5.42 (2.54)	4.97 (2.72)

Following repeated measures mixed ANOVAs, post hoc Scheffe's tests were performed to identify significant differences between grade levels. Data for comparisons include the subset of individuals who filled out all three surveys. *$p < 0.05$, grade 4 versus grade 6; †$p < 0.05$, grade 5 versus grade 6.

4. DISCUSSION

Based on our study, we conclude that the FEMMES Capstone event has had a positive impact on young girls with respect to their interest, confidence, and knowledge of STEM subjects. In almost all cases, post-survey responses were higher than pre-survey responses, with small declines in ratings over the next three months. For girls who attended the Capstone event in two consecutive years, they sustained their increase in interest and knowledge of engineering during this time period. Furthermore, analysis of ratings by girls in the grade subsets revealed a trend of decreasing interest from grade four to six.

TABLE 6: Participant activity ratings on post-survey

	Median rating	*N*
Three Fun Math Problems	8	47
Brain in a Dish	9	31
Chemistry of the Earth	8	48
Creating a 3D Interactive Story	10	85
Dynamix	9.5	92
Environmental Detective	8.5	38
Fun with Fluids	9	47
Games, Probability, and Patterns	9	40
How Ultrasound Works	8	50
Human and Computer Interactions	10	28
It's in Our Genes	9.5	77
Laws of Genetics	9	49
Marvelous Machines and Mechanisms	9	41
Oxygen Can be Hazardous to Your Health!	10	66
Pharmacologists as Sleuths	9	93
Polymers in Action	10	50
Science is SWEet	10	86
Smart Engineering Materials	10	40
Statistics for Better Decisions	9	24
Tales of H_2O	10	86
The Fly and I	10	75
Water Pollution	10	42

4.1 Impact of FEMMES Capstone on Interest, Confidence, and Knowledge of STEM Subjects

Interest, knowledge, and confidence of all three subjects showed significant increases from pre-survey to post-survey. Post-surveys are completed by the participants after immersion in a full day of STEM activities. Thus all of the excitement and emotion is still fresh in their minds so it is not surprising that their ratings increased immediately at the end of the event. These results support those that we previously found in the first cohort of the FEMMES Capstone program (Weston *et al.*, 2008). In that study, no follow-up surveys were administered, precluding any conclusions about persistence of the girls' attitudes. Here we show that generally, girls' attitudes were higher during the follow-up period than prior to the event, with the exception of interest in science and engineering, which declined slightly. While these results are encouraging in general, the slight loss of interest in science and engineering over the three months is not entirely surprising. It is possible that after leaving the excitement of an immersive one-day event, the feelings of interest may have subsided. If so, a program in which girls have more long-term exposure to science and engineering activities would reverse this decline, further discussed below and in the companion paper by Chen *et al.* (2011).

We were most interested in the comparison of mean participant ratings between the pre-survey and the follow-up survey. This analysis provides information on the "long-term" effects of the FEMMES Capstone event. Interest in engineering; confidence in math, science, and engineering; and knowledge of math, science, and engineering showed significant increases in mean participant ratings from pre-survey to follow-up survey. Although these changes were significant, the improvements were small in some cases. This is not surprising given the limited experience (i.e., one day) in which the girls participated. Interestingly, 16 students returned the following year, and they demonstrated a large increase in interest and knowledge in engineering and an increasing trend in all remaining measures (unpublished observations). Thus it is possible that a more sustained experience that engages the girls in fun, hands-on activities in the STEM areas may result in a more pronounced increase in interest, knowledge, and confidence. To this end, we have developed a year-long afterschool program (see accompanying paper by Chen *et al.,* 2011), as well as a weeklong summer day camp on Duke's campus. We are continuing to collect data before and after these programs to assess whether the multiple exposure and longer-lasting format will increase interest in, and confidence and knowledge of the STEM areas.

In addition to limited exposure, there may have been several other factors that limited our ability to demonstrate significant improvement in students' ratings. First, the only areas that failed to show a significant change from pre-survey to follow-up survey were interest in math and interest in science. One possible explanation for the absence of a significant increase in interest in math is that not every participant attended a math activity since there were not enough faculty-led math activities at the Capstone event. Thus we did not have the power to detect increases in interest in math interest over time.

Another factor that may preclude detection of more robust changes over time is a "ceiling effect" in the participants' ratings. Since 10 is the highest possible rating, many students who start out at a 10 could not demonstrate a higher rating for the follow-up survey, even though they may have more positive attitudes. To control for the ceiling effect, we recommend including retrospective questions on the follow-up survey that allow participants to assess qualitatively whether their interest in science, for example, has decreased, stayed the same, or increased. Providing additional questions that assess interest, confidence, and knowledge for math, science, and engineering would not only help control for the ceiling effect but would also enable an assessment of the reliability. Since our survey only had one question assessing interest, confidence, and knowledge for each construct, we did not have sufficient questions to conduct a reliability test.

Third, a potential source of error is that parents may tell their daughters to circle 10s on the pre-survey in hopes that it will be more likely for them to be selected for the program (though we do state that our selection process is on a first-come, first-served basis). For the follow-up survey, perhaps the girls then put down how they really feel about these subject areas. This problem would show an artificial decrease or an increase of a smaller magnitude.

There are two other limitations of our study. One is the potential for a non-response bias. All participants submitted completed pre-surveys as part of their registration packet. Three months after the event, we sent follow-up surveys to the participants via postal mail, with a stamped and addressed return envelope. However, in 2008, only 97 out of 230 (42%) returned the follow-up survey. Perhaps girls who were compelled to fill out the follow-up surveys and mail them back were those girls who were impacted more substantially by the Capstone event and had strong opinions, positive or negative. Although it is possible that demographic differences could explain differences in response rate and outcomes, this is unlikely since the demographic characteristics of our participating population were fairly homogenous (i.e., African American girls).

Second, we did not have a randomized-controlled design to detect the impact of the Capstone event on girls' knowledge and attitudes about the STEM areas. Thus we could not control for the contribution of natural increases in knowledge and attitudes due to learning in school that could have occurred regardless of attendance at the Capstone event. However, because students begin to lose interest in STEM fields in middle school (Gibson and Chase, 2002; Speering and Rennie, 1996; Gonzales *et al.*, 2003)—and this is especially true for girls (Jones *et al.*, 2000), we suggest that the significant increases in mean participant ratings from pre-survey to follow-up survey were not likely a consequence of natural improvement (or even a test/retest phenomenon) but more conceivably an effect of the Capstone program itself.

4.2 Grade Level and Students' Attitudes About STEM Subjects

We were interested in determining whether the FEMMES Capstone event has a greater impact in one particular grade over the others. However, no significant interactions were found between the sequential survey testing results and grade of the participants. Although the number of participants was reasonable, it is still possible that the number of participants was too small to detect a significant difference. However, we did detect differences in the main effects of grade. The 6th-grade girls reported less interest in science and engineering and confidence in engineering compared to their younger peers. These findings agree with previous studies in which students report less interest and enjoyment in STEM domains by the time they enter high school (Alspaugh, 1998; Speering and Rennie, 1996). Speering and Rennie's longitudinal study in 1996 found students to be less enthusiastic about science early in secondary school than they were at the end of primary school. According to the third Trends in International Mathematics and Science Study (Gonzales *et al*., 2003) findings, 4th-grade achievement scores in science and math in the United States were significantly higher than the Trends in International Mathematics and Science Study (TIMSS) international scale average while 8th-grade scores were only marginally higher. This drop in relative performance reflects the decline of interest in math and science as middle school students in the United States progress into higher levels of education. The middle school curriculum that exists in the United States has been criticized for lack of rigor and coherence that are typical of curricula in other countries (Gonzales *et al.*, 2003).

With the focus of our study on female participants, our results also agree with previous studies in which there is a gradual decline of interest in science in young females. Speering and Rennie (1996) found a striking drop in positive survey responses relating to interest and enjoyment in science in girls from 7th to 8th grade. Even though both girls and boys reported decreases in positive science attitudes, girls expressed a steeper disinterest in science throughout secondary school. Similarly, Jones *et al.* (2000) found that 6th-grade female students reported significantly less interest in learning about various science topics than their male peers. More females than males were also found to perceive science as difficult. Our results show that sometime before 6th grade, girls are already starting to lose interest in science and engineering. This can result from the physiological and mental changes during middle school years when girls and boys enter puberty and gender stereotypes in the physical sciences begin to solidify (Jones *et al.*, 2000). Consequently, late elementary school to early middle school years appear to be the critical time period to target students, especially young females, in STEM fields before their interest wavers in the subsequent years. We suggest that even a one-day FEMMES Capstone experience that targets late elementary school girls may provide them with the "hook" that will help to promote their interest and learning in the STEM fields.

5. CONCLUSION

The results from the 2008 and 2009 Capstone events suggest that hands-on workshops and female-to-female mentorship excite young girls about the potential for success in STEM fields. The trends in our data also indicate the potential for a more significant impact through long-term outreach programs, which has led us to develop a six-week-long afterschool program (see accompanying paper by Chen *et al.,* 2011) and a weeklong summer camp. With these three components, the FEMMES program aims to engage young females in STEM fields early on in their academic career in hope that they will continue to explore these subjects in secondary school and throughout the rest of their education.

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APPENDIX A. SCHEDULE FOR A TYPICAL FEMMES CAPSTONE EVENT

Time	Exercise
8:30–9:00 a.m.	Student arrival
9:00–9:35 a.m.	Keynote speech
9:35–10:00 a.m.	Group assignments
10:00–10:45 a.m.	Activity 1
10:45–11:00 a.m.	Break
11:00–11:45 a.m.	Activity 2
11:45–12:00 p.m.	Break
12:00–1:00 p.m.	Lunch
1:00–1:15 p.m.	Break
1:15–2:00 p.m.	Activity 3
2:00–2:15 p.m.	Break
2:15–3:00 p.m.	Activity 4
3:00–3:25 p.m.	Student surveys and evaluations
3:25–3:45 p.m.	Closing remarks
3:45–4:00 p.m.	Student dismissal

APPENDIX B: QUESTIONS FROM PRE-SURVEY/FOLLOW-UP SURVEY AND POST-SURVEY

Pre-Survey and Follow-up Survey

1. Overall, on a scale of 1–10 (10 being very interested, 1 being not interested at all), how interested are you in math? Please circle one number.

1 2 3 4 5 6 7 8 9 10

2. Overall, on a scale of 1–10 (10 being very interested, 1 being not interested at all), how interested are you now in science? Please circle one number.

1 2 3 4 5 6 7 8 9 10

3. Overall, on a scale of 1–10 (10 being very interested, 1 being not interested at all) how interested are you in engineering? Please circle one number.

1 2 3 4 5 6 7 8 9 10

4. Overall, on a scale of 1–10 (10 being you know a lot, 1 being you know nothing), how much do you know about math? Please circle one number.

1 2 3 4 5 6 7 8 9 10

5. Overall, on a scale of 1–10 (10 being you know a lot, 1 being you know nothing), how much do you know about science? Please circle one number.

1 2 3 4 5 6 7 8 9 10

6. Overall, on a scale of 1–10 (10 being you know a lot, 1 being you know nothing), how much do you know about engineering? Please circle one number.

1 2 3 4 5 6 7 8 9 10

7. Overall, on a scale of 1–10 (10 being the best, 1 being the worst), how good are you at math? Please circle one number.

1 2 3 4 5 6 7 8 9 10

8. Overall, on a scale of 1–10 (10 being the best, 1 being the worst), how good are you at science? Please circle one number.

1 2 3 4 5 6 7 8 9 10

9. Overall, on a scale of 1–10 (10 being the best, 1 being the worst), how good are you at engineering? Please circle one number.

1 2 3 4 5 6 7 8 9 10

Post-Survey

1. What did you like most about today?

2. What did you like least about today?

3. Would you come back next year? YES _____ NO _____

If NO, why not?

4. Overall, on a scale of 1–10 (10 being the best, 1 being the worst), how would you rate your experience today? Please circle one number.

1 2 3 4 5 6 7 8 9 10

5. Overall, on a scale of 1–10 (10 being very interested, 1 being not interested at all), how interested are you in math? Please circle one number.

1 2 3 4 5 6 7 8 9 10

6. Overall, on a scale of 1–10 (10 being very interested, 1 being not interested at all), how interested are you in science? Please circle one number.

1 2 3 4 5 6 7 8 9 10

7. Overall, on a scale of 1–10 (10 being very interested, 1 being not interested at all), how interested are you in engineering? Please circle one number.

1 2 3 4 5 6 7 8 9 10

8. Overall, on a scale of 1–10 (10 being you know a lot, 1 being you know nothing), how much do you know about math? Please circle one number.

1 2 3 4 5 6 7 8 9 10

9. Overall, on a scale of 1–10 (10 being you know a lot, 1 being you know nothing), how much do you know about science? Please circle one number.

1 2 3 4 5 6 7 8 9 10

10. Overall, on a scale of 1–10 (10 being you know a lot, 1 being you know nothing), how much do you know about engineering? Please circle one number.

1 2 3 4 5 6 7 8 9 10

11. Overall, on a scale of 1-10 (10 being the best, 1 being the worst), how good are you at math? Please circle one number.

1 2 3 4 5 6 7 8 9 10

12. Overall, on a scale of 1–10 (10 being the best, 1 being the worst), how good are you at science? Please circle one number.

1 2 3 4 5 6 7 8 9 10

13. Overall, on a scale of 1–10 (10 being the best, 1 being the worst), how good are you at engineering? Please circle one number.

1 2 3 4 5 6 7 8 9 10

14. How do you feel about math, science, and engineering after today (circle one)?

Better Worse The same

Why? ____

15. On a scale of 1–10 (10 being you enjoyed it a lot, 1 being you didn't enjoy it at all), how much did you enjoy today's activities?

Morning speeches: 1 2 3 4 5 6 7 8 9 10

(Fill in which activities you attended on the line)

Activity 1: ____

1 2 3 4 5 6 7 8 9 10

What did you like most about this activity?

____

What did you like least about this activity?

____

Activity 2: ____

1 2 3 4 5 6 7 8 9 10

What did you like most about this activity?

____

What did you like least about this activity?

____

Activity 3: ____

1 2 3 4 5 6 7 8 9 10

What did you like most about this activity?

____

What did you like least about this activity?

____

Activity 4: ____

1 2 3 4 5 6 7 8 9 10

What did you like most about this activity?

____

What did you like least about this activity?

____

16. Please rank how important to you do you think the following nine things were to how positive your experience at FEMMES was today? (1 being the most important, 9 being the least important)

____ You got to learn outside of school
____ There were only girls
____ You were able to see females who professionally excel in math, science, and engineering
____ You got to spend the day with college students
____ You liked the specific activities
____ You were able to do hands-on learning
____ The entire day was focused on math, science, and engineering
____ You were able to spend the day with your friends
____ Other: ____

APPENDIX C: ACTIVITY DESCRIPTIONS FOR EACH SUBJECT AREA

Activity	Focus	Description
BIOLOGY		
It's in Our Genes	Genetics	Participants studied the patterns of inheritance of multiple genes by making a gingerbread family. The appearance of each gingerbread cookie reflected the genes it inherited from its parents. Participants learned that by knowing the genotype of parents, it is possible to use basic rules of probability to predict the frequency with which specific traits will appear in their offspring.
The Fly and I	Genetics	In this workshop participants learned how the fruit fly could teach us about how our own bodies work. They looked at a variety of flies under microscopes, observed their physical traits and a few of their behaviors, and then identified mutants in these traits or behaviors from a set of "mystery" flies.
Brain in a Dish	Neurobiology	Students built a neuron while discovering how having different shapes helps neurons to accomplish different goals. Next, students played a game called "synaptic tag" to simulate neurotransmitters being degraded by proteins. Finally, students looked at some real brains to see how all those neurons are "hooked" together into the special organ that makes us who and what we are.
Laws of Genetics	Genetics	Participants learned about some of the principles of genetics and then applied those principals to explore the basis of genetic variation. They looked at their own genetic traits as well as created their own creatures using the laws of genetics.
ENGINEERING		
Environmental Detective	Environmental Engineering	Students learned how to identify pathogens using genetics. They were given a DNA probe for a specific microbe and learned how to use it as a sensor for pathogen identification. They learned about various types of pathogens and how they infect humans.
Dynamix	Electrical and Computer Engineering	Participants experimented and interacted with a sound exhibit in the Duke sound studio to understand processes involved in transforming motion into music. Participants used what they learned to construct their own sound mappings of events in the space.
How Ultrasound Works	Electrical and Computer Engineering	Participants explored the concepts and mathematics behind ultrasound images by sending probes into a box, measuring how the probes interact with the contents of the box, and finally drawing a picture of the contents without ever getting to see them directly.
Tales of $H_2 0$	Environmental Engineering	In this workshop, participants learned water treatment and filtration methods used by our drinking water treatment facilities. They tested different filter designs and observed which design is the most successful.
Smart Engineering Materials	Biomedical Engineering	Participants explored some of the coolest advanced materials like how a piece of metal can "remember" its shape or what happens to magnetic particles when they are reduced in size and made funny-shaped rubbers balls that glow in the dark.
Science is SWEet	Architectural Engineering; Physics; Chemistry	Participants explored architectural engineering focusing on the strength and height of structures and the geometries that serve as strengthening techniques. Participants learned about physics, specifically angular momentum and states of matter. Participants found out what goes into a special goo and the chemistry behind its specific properties.
Marvelous Machines and Mechanisms	Mechanical Engineering	This workshop looked at mechanical objects called mechanisms that make up the components of machines. Participants categorized simple mechanisms and learned about pivots, linkages, effort, load, and fulcrum by sorting common mechanisms like scissors, tongs, etc. They then created their own mechanisms to perform two basic tasks.

APPENDIX C: CONTINUED

Activity	Focus	Description
CHEMISTRY		
Oxygen Can be Hazardous to Your Health!		Participants saw how fast the catalase enzyme works to prevent by-products from forming when we breathe, and investigated the effects of some variables like enzyme concentration and temperature on its activity.
Polymers in Action!		Participants performed several hands-on activities that explored the many different forms of polymers to help them learn the numerous applications they have in everyday life.
Water Pollution	Environmental Chemistry	Participants built a model aquifer and discovered how water is stored underground. They discussed how aquifers represent a part of the water cycle then experimented with the model aquifer and observe how human activities can pollute it.
PHARMACOLOGY		
Pharmacologists as Sleuths	Pharmacology	Participants discussed the origin of aspirin and its cousin, salicylate, and performed experiments to determine if certain plants and products contain this drug. They learned why the drug is found normally in plants and why it is added to products that society uses, and how the drug works.
COMPUTER SCIENCE		
Creating a 3D Interactive Story		Participants learned the basics of computer science programming by creating a 3D virtual world using the programming environment Alice on a laptop. They then learned how to use commands to make objects move, talk, and interact, and how to create events and event handlers. Participants then learned how to combine these components to write a short interactive story.
Human and Computer Interactions		Participants played a simple game of coding and encoding schemes, then watched a segment of a movie that showed how people used to dream of using the computer for more complex tasks, and visited Dr. Wu's lab at RENCI to see how many of the dreams have come true.
MATHEMATICS		
Games, Probability, and Patterns		Students played games, looked for patterns, and created patterns to see ways that math helps us answer a variety of questions.
Three Fun Math Problems	Graph Theory; Pythagorean Theorem; Factorization	*Graph Theory*: Participants found out if given a set of n girls, it is possible for each girl to be friends with exactly m ($m < n$) of them. *Pythagorean Theorem/Geometry*: Consider a triangle with edges a, b, and c. If I construct squares with edges of the sides b and c out of cardboard, is there a way to arrange the cardboards so to have a square of edge a? *Factorization Bee*: Participants chose big numbers, and competed to see which team was the fastest in factorizing the given number.
Fun with Fluids	Applied Mathematics	Participants were introduced to basic fluid dynamics principles, including density and viscosity, as well as different types of fluids.
ENVIRONMENTAL SCIENCE		
Chemistry of the Earth		Participants learned how to melt rocks to prepare them for chemical analysis. Participants then analyzed geologic materials (rocks, soils, waters) to determine what elements they contain.
STATISTICS		
Statistics for Better Decisions		Students defined "fair trade," set up an experiment, collected data, and analyzed the data to assess specific questions about fair trade.