Intervention designed to increase interest in engineering for low-interest, K-12 girls did so for boys and girls

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Introduction

Engineering remains a field with disproportionately low representation of women and individuals from underrepresented minority (URM) groups. As early as middle school, these groups start losing interest in science, technology, engineering and math (STEM) fields (National Science Foundation, 2004; Driver, 1985). Thus, early interventions that spark interest and encourage pursuit of STEM areas are greatly needed. Biomechanics is a highly relatable, interdisciplinary field with ties to engineering, medicine, and athletics. Previous studies at a college-wide engineering outreach event (Francis et al., 2016; Francis et al., 2017) have demonstrated the potential for hands-on, biomechanics-based activities to teach engineering principles to K-12 students. A recent study (Francis et al., 2017) indicated that boys participating in these activities had a higher interest in engineering than girls. This study also showed that biomechanics-based activities could increase interest in considering careers in engineering, regardless of initial interest. Of note, when both boys and girls had little to no interest in engineering, boys were more easily drawn in by the outreach activities than girls. The challenge with engaging girls in engineering may be a reflection of intrinsic differences such as gender stereotypes (Bieg et al., 2015), and psychological factors (Stoet et al., 2016) between boys and girls that are more pronounced at low individual-interest levels. Thus, it may be necessary to tailor interventions (e.g., biomechanics-based activities) that target girls with low interest in engineering to increase their level of engagement.

Accordingly, there were two primary goals of this study. The first goal was to determine whether a partially new set of biomechanics-based activities were similarly impactful as a different set of activities used in a previous study. This goal would in fact test whether activity type (i.e., biomechanical) or the actual activities themselves were impactful. The second goal was to investigate the impact of an intervention targeted at increasing interest in low-interest girls at a college-wide engineering outreach event.

Methods

Protocol

We surveyed (Fig. 1) students attending an engineering outreach event before and after participating in up to 10 interactive biomechanics-based activities. The set of 10 biomechanics-based activities and the design of the surveys used were similar to those in a previous study (Francis et al., 2017).

<u>Pre-Activities Statements/Questions</u>

1. I enjoy learning about engineering even when it is very difficult
2. I work on projects that are like engineering outside of school at least once a week
3. Knowing about engineering is extremely valuable to me
4. I know way more about engineering than other kids I know
5. Compared to other students at my school, I am way better at doing engineering work
6. I might want to be an engineer when I grow up

<u>Post-Activities Statements/Questions</u>

1. I think this demonstration was very exciting
2. After visiting the lab, I would like to learn more about engineering
3. What we learned in this lab is useful for me to know
4. I might want to be an engineer when I grow up
5. To me, the activities in this lab were very entertaining
6. I'd like to learn more about the topics we learned about in this lab
7. I learned valuable things during the demonstration
8. What grade are you in
9. What is your gender
10. What is your race/ethnicity

Figure 1: Pre- and Post-Activities Statements/Questions.

Six of 10 activities from the previous study were repeated in this study. They were as follows: (1) measurement of maximum jump height using a Microsoft Kinect system (Microsoft, Redmond, WA) for comparison to professional athletes and animals; (2) measurement of walking characteristics using Wii Balance Boards (Nintendo; Redmond, WA); (3) measurement of muscle activity using surface electrodes (Back Yard Brains; Ann Arbor, MI); (4) investigating object properties in a virtual reality (VR) environment using a haptic robot and VR system; (5) investigating human walking patterns using a computer simulation of gait (BioMotion Laboratory, Queens University; Kingston, Ontario, Canada); (6) measurement of basketball dribbling characteristics with a smart basketball (InfoMotion Sports Technology; Dublin, OH). The remaining four activities were new. They were as follows: (1) exploring compression in materials; (2) investigating anatomical features of lower extremity bones; (3) design of an ankle-foot orthosis; and (4) learning about the scientific contributions of university researchers in an engineering trivia game.

To address our second goal, we developed the engineering trivia game as an intervention to increase engineering interest for girls with little to no initial interest in engineering. Girls may view engineering more favorably if they see it (1) as a field that helps people (Jones et al., 2000, Weisgram and Bigler, 2006), and (2) as a field in which women have made significant contributions (Buck et al., 2008). Hence, our intervention focused on these two aspects to increase girls' interest in engineering. Briefly, the materials for the activity consisted of a poster board that contained engineering problems, possible engineering solutions to each problem, and possible male and female engineers who discovered the solution to each problem (Fig. 2). First the facilitator presented a problem to the participants, and then three possible solutions. One was the correct solution, and the others were seemingly plausible but incorrect solutions. The participants were given an opportunity to guess the correct solution. Next, the facilitator presented six names and pictures of the scientists or engineers (3 men, 3 women) who might have discovered the solution and asked the participants to guess which of the scientists/engineers made the discovery.

Two different versions of this activity were used (Table 1). In each version, the gender of the facilitator and the gender of the scientist/engineer who made the discovery were varied. Half of the time the "Female-Accomplishment Intervention" was used, and half of the time the "Male-Accomplishment Intervention" was used. Participants were given correct answers if they answered incorrectly. After all three problems were answered, the facilitator asked what each solution had in common, and what each engineer or scientist had in common. The answer for the "Female-Accomplishment Intervention" was that they were all women and the solutions helped make peoples' lives better. The answer for the "Male-Accomplishment Intervention" was that they all made great technological discoveries; the facilitator did not emphasize that all three engineers/scientists were male. To later identify which participants completed the trivia game activity, and thus should be included in the intervention group, the facilitator marked the surveys of those who participated in the trivia game activity with a stamp unique to the version of the intervention that they completed.

Engineering Problem	Possible Solutions	Scientist/Engineer who Discovered/Created Solution
Problem statement 1	Solution A	Female A
		Female B
		Female C
	Solution B	
		Male A
		Male B
	Solution C	Male C
Problem statement 2	Solution A	Female A
		Female B
		Female C
	Solution B	
		Male A
		Male B
	Solution C	Male C
Problem statement 3	Solution A	Female A
		Female B
		Female C
	Solution B	
		Male A
		Male B
	Solution C	Male C

Figure 2: Layout of Board Used in Engineering Trivia Game

Table 1: Explanation of Two Versions of Engineering Trivia game Intervention

Intervention Version	Gender of Facilitator	Gender of Scientist/Engineer
Female-Accomplishment	Female	Female
Male-Accomplishment	Male	Male

Each student at the outreach event was asked to complete both a pre-participation and post-participation survey (Fig. 1). As in previous work, the pre- and post-surveys were designed to measure individual (items #1-5 on pre-survey) and situational (items #1-3 & 5-7 on post-survey) interests in sub-sets of students self-identified by gender, grade level, ethnicity and initial interest in engineering using a 7-point Likert scale (1: strongly disagree; 7: strongly agree). Pre-participation questions were printed on one side of a piece of paper; post-participation questions were printed on the reverse side (Fig. 1).

Data Analyses

Individual interest scores were calculated by averaging the five individual interest items on the pre-survey questionnaire. Situational interest scores were calculated by finding the average of the six situational interest items on the post-survey questionnaire. Interest in an engineering career was assessed based on items #6 and #4 on the pre- and post-survey questionnaires, respectively. The threshold for low and high levels of interest were determined by the range of values less than and greater than the mean for individual interest.

An ANOVA test (*alpha* < 0.05), conducted using *R*, was used to compare situational and career interest levels in participants pre- and post-, and as functions of demographic factors and participation in the engineering trivia game intervention activity. Where appropriate, *t*-tests (*alpha* < 0.05) were used as post-hoc tests when significant effects were identified in the ANOVA test.

Results

Over two-days, we collected 701 completed pre- and post-participation surveys (93% of total) from students. Of these 701 participants, 44% were girls, and 22% were members of an URM group.

Many of the findings in this study were similar to those in a previous study (Francis et al., 2017). For example, after participating in the outreach activity, the number of boys and girls who indicated they would pursue a career in engineering increased significantly with post-activity career interest scores ($M = 4.77$, SD = 1.86) being significantly higher than pre-activity career interest ($M = 4.42$, SD = 1.94; $t(700) = 7.05$, $p < 0.001$) scores. We also found that boys and girls with high individual interest experienced a greater level of situational interest than those with low individual interest ($p < 0.00001$, Table 2). In general, situational interest was greater for boys than for girls ($p<0.00001$, Tables 2, 3).

In this study, an ANOVA (Table 2) revealed group differences in situational interest due to ethnicity ($p = 0.002$), grade level ($p = 0.014$), and intervention condition ($p = 0.019$). Post-hoc t-tests (Table 3) revealed that situational interest was greater for Asian/Pacific Islander than for White, Latino and African-American participants ($p < 0.05$). Situational interest was also greater in elementary school-aged students as compared to middle school-aged students ($p < 0.05$).

Specific to the intervention designed to increase interest in engineering in girls with little to no interest, 151 participants (40% female) engaged in either the male- or female-accomplishment intervention. A post-hoc comparison of means demonstrated that participants in the female-accomplishment intervention did not have a significant difference in situational interest compared to those in other conditions, while those in the male-accomplishment intervention had higher situational interest for both boys and girls than those in the control condition ($p = 0.015$, Table 3). There was no significant interaction of gender within the intervention ($p = 0.07$, Table 2).

Table 2: ANOVA results for differences in situational and career interest variables

		df	*F*	*p*
Situational Interest	Grade	2	4.27	0.014*
	Gender	1	26.15	<0.00001*
	Ethnicity	5	3.85	0.002*
	Intervention Activity	2	4.01	0.019*
	Interest Level	1	136.87	<0.00001*
	Intervention Activity * Gender	2	2.67	0.07
Difference in Career Interest	Grade	2	0.33	0.72
	Gender	1	1.75	0.19
	Ethnicity	5	1.27	0.28
	Intervention Activity	2	1.89	0.15
	Interest Level	1	7.88	0.005*
	Intervention Activity * Gender	2	0.27	0.77

Table 3: Pairwise comparisons for differences in situational interest

	n	*M*	*SD*	*p*
high interest	346	6.01	0.89	< 0.00001
low interest*	355	4.98	1.21	
male	392	5.67	1.09	< 0.00001
female*	309	5.26	1.25	
White	513	5.44	1.14	0.0004
Latino	63	5.43	1.3	0.018
African-American	31	5.37	1.35	0.038
Asian/Pacific-Islander*	51	6.04	1.08	-
Native American	9	5.35	1.48	0.44
Other	34	5.56	1.28	0.33
Elementary*	327	5.58	1.22	-
Middle School	353	5.38	1.16	0.044
High School	21	5.87	0.82	0.104
No-Intervention	550	5.45	1.19	0.015
Male-focused Intervention*	90	5.76	0.97	-
Female-focused Intervention	61	5.44	1.28	0.182

Note: * = comparison group

Discussion

The primary goals of the current study were: (1) to determine whether a partially new set of biomechanics-based activities were similarly impactful as a set used previously, and (2) to investigate the impact of an intervention targeted at increasing interest in low-interest girls at a college-wide engineering outreach event. The first key finding was that a partially new set of biomechanics-based activities, used in this study, were similarly impactful as that used previously. The second key finding was that the male-accomplishment intervention positively impacted both boys and girls, while the female-accomplishment intervention did not positively impact girls as it was designed.

The first key finding that biomechanics-based activities continued, from year to year, to positively impact both situational and career interests highlights the potential for utilizing biomechanics as a tool to improve engineering interest in K-12 students regardless of their initial interest. This is the second consecutive year that we have shown increases in students' interest in engineering following interaction with a set of biomechanics activities. This finding perhaps indicates that activity type (i.e., biomechanical)—rather than the activities themselves—is the most important factor for increasing the situational interest levels of students. This might be because biomechanics is a highly relatable, interdisciplinary field with ties to engineering, medicine, and athletics, and thus draws in more students than another, less relatable engineering discipline. Therefore, future outreach and K-12 activities designed to increase interest in engineering should consider using biomechanics-based activities.

The second key finding was that the male-accomplishment intervention positively impacted both boys and girls, while the female-accomplishment intervention did not have a positive impact, even for girls, as it was designed. While it is beneficial that one of the interventions did positively impact students that participated, the primary goal was to increase the interest in engineering of low-interest girls by challenging gender stereotypes about women in science. We hoped that a female-focused intervention would have had the greatest impact on low-interest girls; however, we were surprised to find that only the male-accomplishment intervention had an impact on the situational interest of boys and girls in the study. Thus, assuming that the facilitators were given the same instructions and led the interventions in the same way, then the female-accomplishment activity as designed was not the best way to inspire low-interest girls to achieve similar interests in engineering as boys. However, it was unexpected that the male-accomplishment intervention was correlated with higher situational interest scores for the girls.

There are several possible explanations about why the gender-focused intervention failed to preferentially increase K-12 girls' interest in engineering. One is that the bias that men are innovators was not overcome through the appeal to the girls' personal values (Dasgupta 2014). Another is that the simple design of the activity (e.g., simply including a female engineer's name and picture) was not enough to engage a meaningful connection with the young girls. Research into the cognitive processes of adolescent girls suggest that their initial image of female role models was that they could not have a connection with them (Buck, 2008). Research suggests that, more than gender, these role models are effective when they are more non-stereotypical role models (Cheryan et al., 2011). Future work should focus more on the "non-science nerd" nature of the role model (e.g. highlighting their non-professional interests and accomplishments).

This study does have limitations. First, the interaction between the gender of the facilitator and the gender-focus of the intervention (i.e., male facilitator leading a female-focused intervention) was not explored. Future work to improve upon the intervention activity to target specific gender groups should consider all possible interactions. Second, we did not control for the order in which students completed the biomechanics activities. Thus, the impact of the gender-focused intervention could have been different if the students completed it before or after other activities. Third, we did not assess the long-term effects of biomechanics activities to determine whether the increased interest in engineering stayed with these students. Future work will focus on more targeted outreach events with smaller groups of students, which would make long-term follow-ups and repeated interventions possible.

In conclusion, we have shown for two straight years that biomechanics-based activities can increase the interest levels of K-12 students in pursuing an engineering career. There is still a need for targeted activities to increase girls' interest in engineering to match that of boys. The continued motivation that we have to improve these biomechanics activities is due to the desire to build an online repository of biomechanics activities that are well-tested, education standards-compliant, and both educational and inspirational to a diverse group of students.

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