What Matters to My Future: STEM Int-her-est and Expectations

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***Abstract*— This paper investigates the effect Science, Technology, Engineering, and Mathematics (STEM) Problem-Based Learning (PBL) activities have on single-sex classes and how these experiences affect students' attitudes toward STEM careers. To close the gap of underrepresentation of females in STEM, research suggests single-gender classes should be implemented. Single-gender classes have shown to improve female interest in STEM fields. A quasi-experimental study was conducted to assess female and male interest and attitudes toward STEM fields and careers. There were 97 participants in 7th through 12th grade who attended a one-week STEM Camp. Of those, 50 females participated in an all-female option, 23 males participated in an all-male option, and 25 campers participated in a co-ed option. Participants completed a survey using a Likert scale to rate their perceptions of STEM. The results were contrary to previous research indicating that both single-gender classes had lower affect toward engineering than the mixed gender group. Females in the mixed group rated their attitudes and interest toward STEM fields and careers statistically significantly higher than the females in the all-female group in three of the four constructs (knowledge, importance, and career). The findings support the inclusion of STEM PBL in classrooms because there were no significant differences between the class type after participating in a one-week STEM camp. Through the use of STEM PBLs, females' interest in STEM careers is equal to male interest.**

Keywords—single-gender, single-sex, mixed gender, STEM PBL, females, STEM

I. INTRODUCTION

It is often perceived that male students outperform female students in STEM courses. However, researchers have noted that female students perform equally, or sometimes better, in STEM courses than their male counterparts, despite having less confidence and interest in these fields [1-6]. By middle school, females are half as likely as their male peers to possess STEM-related career aspirations [2, 7]. The results from these studies underscore the critical need for early intervention starting in middle school to foster and maintain female students' interest in STEM fields. Therefore, this study presents the effect science, technology, engineering, and mathematics (STEM) project-based learning (PBL) activities have on single-gender classes and how these experiences affect middle and high school students' attitudes toward STEM interest and careers. This study lies in the nexus of enactivism and constructivism. Both learning theories deal with high levels of engagement for the building of knowledge. However, with enactivism there is greater likelihood that females in an all-female class might exhibit collaborative engagement when compared to females in a co-educational environment [8]. Because research indicates that females in co-educational settings tend to allow males to engage to a greater extent with kinesthetic materials, females' learning is subjugated to that of the males [9]-[10]. Increasing females' interest in STEM courses should have a direct effect on their perceptions of STEM fields, which should impact their desire to choose a career in a STEM field. Female students may be hesitant to participate in informal STEM activities because they are less confident and often feel discouraged [11]. Therefore, providing opportunities to work alongside female STEM professors may encourage reluctant females to participate and potentially empower them to pursue STEM careers [12]. In order to determine how STEM PBL activities impact students in single-gender classes and influence their attitudes toward STEM, we asked the following research question: How do STEM PBL activities in single-gender classes influence students' attitudes toward STEM interest and careers by their gender?

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II. LITERATURE REVIEW

A myriad of factors contributes to the underrepresentation of females in the STEM pipeline and create a self-reinforcing cycle. Researchers have found that women are underrepresented in STEM career fields because of the fear and discouragement they face when engaging in advanced STEM subjects, which

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negatively influences their interest, motivation, and persistence in pursuing STEM careers [7]. In addition, the gender gap in pay and limited benefits for females (e.g., maternal accommodations) in STEM fields may deter females who are interested in pursuing STEM career paths [13, 14]. The stigma that females are inferior to men in STEM environments is still prevalent today and is fostered by the expectations set by society's norms, in which academic and occupational fields are stereotyped as appropriate for specific genders. These stereotypes contribute to the gender gap within STEM-related disciplines [15]. Unfortunately, students are aligning their educational goals within the context and expectations of these societal stereotypes, fostering and maintaining a gender gap within the educational system [15]. The gender gaps created in work places, caused by underrepresentation of females in STEM classes, is a continuous cycle that leads to discouragement time and time again. continue the cycle of discouragement students are facing in their courses [1] [7]. Fear and discouragement can develop self-doubt in a student's ability projecting negativity on STEM environments, decreasing a student's value and opinion of STEM fields [16]. Underrepresentation of females in the STEM fields are caused by the stereotypes that society places on the success of females in STEM fields.

Historically there have been several attempts to increase female participation in STEM fields, one method that was tried was instruction in single-sex classrooms. Various research studies have been conducted to determine the effectiveness of single-sex classrooms, results from these studies contradict one another. For instance, in two studies, females in single-sex mathematics or science classrooms proved to be significantly more confident in their abilities than students in co-ed classrooms [1, 5]. Furthermore, the results from another study found high-school students from an all-boys school showed an increase in their interest and attitudes toward STEM fields [17]. However, other research has indicated single-sex classrooms tend to have a larger impact on females, while males have better performance in co-ed classrooms [3]. Due to the lack of consensus with prior research, many single-sex classrooms have disappeared for cost effective and spatial purposes [4]. Research has been inconsistent with its arguments for or against single-sex instruction for both genders, however due to the positive benefits seen for females in single-sex classrooms there is a push for all-female classrooms to promote their interest in underrepresented fields, particularly in STEM.

There is inconclusive research to suggest that females and males in single-sex classes perform as well as or equal to their counterparts in mixed-gender classrooms. Some researchers have found that separation of genders in classrooms do not lead to a significant difference on the students' perceptions of the classroom environment and their personal performance [18]. Conversely, there are various aspects of single-sex classrooms that attest to an increase in confidence, performance, and perception of STEM for females, these positive affects do not infer that the retention rate of females choosing STEM careers will increase or decrease [2, 17]. Despite the positive effects of female attitudes toward STEM fields seen in single-sex classrooms, females continue to be underrepresented in STEM majors.

The atmosphere of the classroom setting has the potential to impact students' perceptions and interests in STEM fields. Young females are empowered more by a climate that fosters support and encouragement of STEM learning than by the type of classroom setting (i.e. single-sex vs co-ed) [6]. Female students have a positive attitude about mathematics in both single-sex and co-ed classrooms because of the environment within those classes [6]. The structure of STEM courses young students complete has the potential to alleviate the fear young women face by fostering an active-learning community within the classroom, which will increase student engagement and retention leading to higher enrollment and success from females [19]. Research has found that the learning environment has more of an impact than the classroom setting. Creating these environments and exposing students to STEM project-based learning (PBL) activities can positively influence their likelihood of continuing toward a STEM career [20]. Since there are negative stigmas that can impact a student's career decision, promoting engaging activities that will encourage them to pursue STEM is encouraged [20].

Based on prior research, there is a need for further research to determine if females in single-gender settings show higher interests toward STEM fields than females in mixed gender settings. This study will build on previous research to shed light on single-gender education for females and males participating in STEM PBLs.

III. Methodology

For this study, a quasi-experimental design (cf. [21]) was applied to understand the impact single-gender classes infused with STEM PBL have on participants' attitudes toward STEM subjects and college and career interests compared to co-educational (co-ed) or mixed gender classes. The design of the study consisted of one pre-test followed by multiple post-tests. Students were assigned to one of three STEM camps: all-female, all-male, or mixed gender STEM. Data were analyzed using *t*-tests, effect sizes, and 95% confidence intervals. Effect sizes and confidence intervals have been suggested to show the practical importance of the educational studies, [22, 23]. To measure the group mean differences, Cohen's *d* effect size (e.g., [24]) was applied. For the purposes of this paper a Cohen's *d* greater than *.25* standard deviations increase will be considered *practically* important because a quarter standard deviation represents meaningful change on the Likert scale on which the constructs were measured. The 95% confidence intervals should be interpreted as indicating that 95% of the time the reported confidence interval will capture the reported mean from a similar study [25, 26]. The value of reporting both effect sizes and confidence intervals is that they foster meta-analytic thinking and offer the potential for aggregating finding across studies to develop important benchmarks for what the intervention can be expected to deliver should it be replicated.

A. Participants

There were 98 participants in 7^{th} through 12^{th} grade who attended one-week residential STEM camps. Of those, 50 females participated in an all-female camp option, 23 males participated in an all-male camp option, and 25 campers (Female=13) participated in a mixed gender camp option. A randomized sample of 24 females was selected from the all-female camp for comparison purposes; therefore, the sample size included the 24 females along with the total number of participants in the all-male and mixed gender camp options (N=72).

B. Setting

The summer camps are offered on a first come, first served basis, and participants who can afford the camp are charged a modest fee while those who cannot are provided varying levels of financial support based on need. During the summer of 2017, there were a total of seven camps planned to be offered. Of these camps, one was designed to be an all-girls camp, while the other six were designed for a co-ed, or mixed gender cohort of students. The structure and activities in each of these camps were created to develop a community of learners through engagement in STEM activities, discussion panels, university lab tours, and nightly social activities. However, the all-girls camp was uniquely designed to promote women in STEM. The specialized camp schedule included three STEM courses, panel discussions, and lab tours that incorporated aspects of science, technology, engineering, and mathematics specifically designed by female university faculty and their graduate students. The camp included STEM PBL activities taught by an all-female group of instructors that incorporated cosmetic chemistry, artistry in coding, and the use of micro-controllers to create interactive plush toys for homeless children. In addition, panel speakers at this camp were women in STEM fields who worked at STEM-based companies. The six mixed gender camps were also designed to include panel discussions, lab tours, and three STEM-focused courses. Panel discussions were led by speakers from various fields, such as engineering students, engineers, and college admissions employees. Participants were also given tours of STEM labs on campus to observe the various forms of STEM research being conducted within a wide variety of disciplines. In addition, camp courses incorporated STEM activities of broad interest, including constructing bridges, piloting drones, creating fidget spinners (physics), and assembling equipment to generate renewable energy (e.g., solar recharging station). Although these six camps were designed and intended for a mixed gender student cohort, one of the camps had an entirely male enrollment by chance. The remaining five mixed gender cohorts consisted of 38% females and 62% males. The naturally occurring dichotomy of two single-gender camps provided a unique research opportunity that allowed researchers to examine the influence of the camps on three different groups: all-female, all-male, and mixed gender. This was of interest because it can be assumed that all of the participants were interested in STEM or at least each of their parents was sufficiently interested in STEM to facilitate their child's participation. Females who had an interest in STEM but wanted the option to attend an all-girls camp had an opportunity to do so and, comparatively, females who had no preference for camp type, or who wanted to attend a mixed gender camp also had an option.

C. Instrument

The Student Attitudes toward STEM (S-STEM) Survey [27] was modified and administered to participants on the first day of camp and the last day of camp. For each survey item, participants used a Likert Scale to rate the statement, the ratings ranged from strongly disagree (1) to strongly agree (5). The S-STEM survey measured students attitudes toward STEM subjects and college and career interests. The S-STEM survey has undergone reliability and validity testing through the Friday Institute for Educational Innovation [27]. Researchers found the original survey had four clear constructs measuring student attitudes toward: 1) mathematics, 2) science, 3) engineering and technology, and 4) 21st century skills. The reported psychometrics, Cronbach's alpha reliability levels for each of the four constructs were found to be above 0.89 [28]. The construct validity was assessed using exploratory factor analysis [29]. The items loaded on the constructs as anticipated, indicating reasonable fit to the proposed construct. However, we modified the survey to include additional items that would enable us to better determine students' attitudes toward STEM subjects and career interests. The calculated reliability reported for the modified survey ranged from 0.83 and 0.92. This paper contains a report of the survey responses indicating students' attitudes toward the knowledge and importance of careers in STEM fields (see Table I) and how these attitudes changed after participating in a one-week STEM camp. Four new constructs were created to reflect student responses to the modified survey and disaggregate the data: 1) knowledge, 2) importance, 3) career, and 4) success. Table I contains the original questions from S-STEM as well as the questions that were added to gain further insight into students' attitudes toward STEM fields and careers.

TABLE I. MODIFIED S-STEM SURVEY & REVISED CONSTRUCTS

Construct	Survey Question
Knowledge	Q5 I will need a good understanding of math for my future work. (added) Q13 I expect to use science when I get out of school. (original) Q14 Knowing science will help me earn a living. (original) Q23 Understanding engineering concepts will help me earn a living. (added)
Importance	Q1 Math is important for my life. (added) Q15 I will need science for my future work. (original) Q17 Science will be important to me in my life's work. (original) Q25 Designing products or structures will be important for my future work. (original)
Career	Q3 I would consider choosing a career that uses math. (added) Q12 I would consider a career in science. (original) Q27 I would choose a career that involves building things. (added)
Success	Q30 I believe I can be successful in a career in engineering. (original)

IV. RESULTS

Results from the modified S-STEM survey were analyzed using effect sizes, 95% confidence intervals, and independent sample *t*-tests using the camp students attended as the grouping variable. The purpose was to determine the effects of STEM

PBL activities within the single-gender or mixed-gender classes on attitudes and interests toward STEM fields and careers with special interest in female performance.

Effect size estimates are measures of the magnitude of relationships grouped into one of two groups: (a) variance-accounted- for or a square world metric or (b) standardized mean differences. The APA Task Force on Statistical Inference [23] suggested that providing some indication of the effect provided a practical and theoretical advantage for theory building the practice over the overreliance of researchers on simply rejecting the null hypothesis.

Confidence intervals provide important information about both location and precision of the obtained point estimate. The advantage of using 95% confidence intervals is that they can provide the same inferential dichotomous decision making points of either rejecting the null or failing to reject but also supports meta-analytic thinking. Therefore, the 95% confidence intervals will be interpreted according to guidelines [26] of a 25% or less overlap between two groups on the same dependent variable indicated alpha < 0.05 and two completely disjoint intervals is approximately alpha < 0.01.

A. Single-gender and Mixed Gender Group Results

Effect sizes and confidence intervals were calculated to determine the true effects that single-gender or mixed gender groups had on participants' attitudes and interests toward STEM fields and careers. Males in the all-male group and participants in the mixed gender group had higher attitudes and more interest in STEM fields and pursuing a STEM career than the females in the all-female group on each of the four constructs: 1) knowledge of STEM concepts, 2) importance of STEM content, 3) interest in pursuing a STEM career, and 4) success in an engineering career (see Table II). The magnitudes of the effect size for importance of STEM content (d = -0.71) and success in a career in engineering (d = -0.52) were impressive between the all-female and all-male groups indicating a greater effect for males. Results from the t-tests showed the males in the all-male group had statistically significantly higher perceptions of success in an engineering career than females in the all-female group (see Table II). The participants in the mixed gender group ranked their interest in pursuing a STEM career and being successful in a STEM career by more than half of a standard deviation higher than the females in the all-female group (see Table II). Participants in the mixed gender group had higher attitudes and interests in STEM fields than the males in the all-male group. However, none of these differences were statistically significant.

TABLE II. EFFECT SIZES AND 95% CIS BY GROUP ON POST-TEST SCORES

Groups	Co[a]	$\bar{X}_1$	SD_1	$\bar{X}_2$	SD_2	*Cohen's* *d*	95% CI Lower	95% CI Upper
Female (n= 24) vs Male (n=23)	K	15.08	3.03	16.54	3.29	-0.46	-3.32	0.40
	I	14.75	2.83	16.72	2.69	-0.71	-3.59	-0.35
	C	10.58	1.81	11.59	2.66	-0.45	-2.34	0.32
	S	3.38	1.13	3.94	1.00	-0.52	-1.19	0.07
Female (n= 24) vs Mixed (n= 25)	K	15.08	3.03	16.44	3.17	-0.44	-3.14	0.42
	I	14.75	2.83	16.04	3.47	-0.41	-3.11	0.53
	C	10.58	1.81	11.96	2.07	-0.71	-2.50	-0.26
	S	3.38	1.13	4.12	1.01	-0.69	-1.36	-0.12
Male (n=23) vs Mixed (n= 25)	K	16.54	3.29	16.44	3.17	0.03	-1.78	1.98
	I	16.72	2.69	16.04	3.47	0.22	-1.14	2.50
	C	11.59	2.66	11.96	2.07	-0.16	-1.75	1.01
	S	3.94	1.00	4.12	1.01	-0.18	-0.76	0.40
Female (n= 24) vs Females in Mixed (n= 13)	K	15.08	3.03	17.15	2.07	-0.76	-3.98	-0.16
	I	14.75	2.83	16.85	2.57	-0.77	-4.02	-0.18
	C	10.58	1.81	12.38	1.71	-1.01	-3.04	-0.56
	S	3.38	1.13	3.85	1.14	-0.42	-1.26	0.32
Male (n=23) vs Males in Mixed (n= 12)	K	16.54	3.29	15.67	4.00	0.25	-1.70	3.44
	I	16.72	2.69	15.17	4.17	0.48	-0.81	3.91
	C	11.59	2.66	11.5	2.39	0.04	-1.77	1.95
	S	3.94	1.00	4.42	0.79	-0.51	-1.16	0.20

a. Note. Co – Constructs, K – Knowledge, I – Importance, C – Career, S – Success

B. Single-Gender and Gender in Mixed Gender Group Results

Results from the females in the all-female group and females in the mixed gender group were analyzed to determine any differences. According to Table II, the effect sizes for knowledge of STEM fields (d = -0.76), and importance of STEM fields (d = -0.77) were striking in the sense that they represented more than three-quarters of standard deviation lower than the females in the mixed gender group. The effect size for choosing a career in a STEM field (d= 1.01) was more than one standard deviation higher than the females in the all-female group for the females in the mixed gender group. Females in the mixed group rated their attitudes and interest toward STEM fields and careers statistically significantly higher than the females in the all-female group in three of the four constructs (knowledge, importance, and career) on the post-test (see Table II). Males in the mixed gender group were compared to the males in the all-male group, the magnitude of the effect size between the two favored the males in the mixed gender group (see Table II). The t-test indicated that males in the mixed gender group was not statistically significantly higher (p > .05) than the males in the all-male group, this was most likely due to the small sample of the males in the mixed gender group (see Table III). Table III contains all the comparisons of interest, with a priori comparisons among males, females, and mixed gender groups across a subset of factors. For example, there was no planned comparison between females and males on knowledge or career because of the direction and magnitude of the obtained effect reported in Table II.

TABLE III. *T*-TESTS AND *P*-VALUES BY GROUPS ON POST-TEST SCORES

Groups	*Co*[b]	*T*	*p*
Female (n= 24) vs Male (n=23)	I	-2.44	0.19
	S	-1.79	0.08
Female (n= 24) vs Mixed (n= 25)	C	-2.47	0.02
	S	-2.43	0.02
Female (n= 24) vs Females in Mixed (n= 13)	K	-2.19	0.04
	I	-2.22	0.03
	C	-2.94	0.01
Male (n=23) vs Males in Mixed (n= 12)	S	-1.44	0.16

b. Co – Constructs, K – Knowledge, I – Importance, C – Career, S - Success

V. DISCUSSION

The overall effect showed that single sex classrooms were not uniformly superior to the mixed gender environment. However, contrary to some research [17], the effects for the all-male group was practically important as compared to the males in the mixed group on all factors except for Success and importantly there was no effect on Career. The effect for the all-female group was negative when comparing to the all-male group or the females in the mixed gender group. Again, this is contrary to other published studies where females tended to have higher affect, attitude, and achievement when in single sex classrooms [1-6], [14], [30].

The findings support the inclusion of STEM PBL in classrooms because there were no statistically significant differences for females in the all-female camp option in their attitudes toward STEM fields and career interest after participating in a one-week STEM camp. Prior research supports utilizing single-gender classrooms to increase female interest and achievement in STEM [1-6], [30]-[3, 31, 32], but this could be due to the use of traditional teaching methods used in most schools. Through the use of STEM PBLs in mixed gender settings, females' interest in STEM careers is statistically significantly higher than when females are in a single gender setting. While most studies have focused simply on creating single gender groups as the variable of interest for comparison our dependent variable was student interest and both groups experienced innovative, contextualized, and highly focused engineering activities.

A. Single-gender and Mixed Gender Group Results

Findings on the post-test indicated females in a single-gender camp were less inclined to pursue a STEM field or career than participants in an all-male camp option or a mixed gender camp option. These results are surprising considering the all-female camp was centered around empowering women and girls to pursue STEM fields, by having all female faculty, all-female speakers during the panel, and incorporating STEM related activities that would be of interest to females. There were no statistically significant differences between the males in the all-male group and the mixed-gender group indicating males would most likely be equally interested in STEM fields whether in a mixed group or a single-gender group. These results support the inclusion of STEM PBL in the classrooms since there were no statistically significant differences for the females in a single-gender camp.

B. Single-gender and Mixed Gender Group Results

Surprisingly our results do not reflect prior research which supports having single-gendered classrooms [1-6]. When the females in the all-female group were compared to the females in the mixed group, the females in the mixed group had more positive attitudes and interest toward STEM fields and careers. The females in the mixed group were more confident in their knowledge of STEM content, felt STEM topics were more important for their life, and were more likely to pursue a STEM field than those females in the all-female group. As mentioned before, this is very interesting because females in the all-female option were empowered throughout the week by female instructors and speakers, while the females in the mixed gender option were empowered by both male and female instructors and speakers throughout the week. The males in the all-male group ranked knowledge and importance of STEM fields higher than males in the mixed gender group. However, males in the mixed gender group felt they would be more successful in an engineering group over the males in the single-gender group. This was not found to be statistically significant due to the low sample size for the males from the mixed gender group.

Overall, the results from this study indicate that females have more positive attitudes about STEM fields and pursuing a STEM career when exposed to STEM PBLs in mixed gender settings. Participants in the mixed gender groups tended to be more interested in STEM fields and had higher positive perceptions of being a successful engineer when engaged in STEM PBLs that enhanced their critical thinking, problem solving, communication, and team work skills. While many studies (e.g. [1-6], [30]-[3, 31, 32]) advocate for females in single-gender classrooms, our results indicate this may actually deter females from pursuing a STEM field or career. One interesting finding in prior research was that men had higher self-ratings than women (cf., [33]) and to some extent this finding was supported in the current study.

VI. CONCLUSION

This study focused on the impact single-gender classes or mixed gender classes would have on participants' attitudes toward STEM fields and interest in careers. Prior research has indicated that single-gender classes will increase females interest in STEM majors [1-6]. However, our results indicated that females in mixed classes actually have more positive attitudes toward STEM fields than females in the single-gender classrooms. This could be due to the implementation of STEM PBLs in the one-week STEM Camp.

Prior research has focused on traditional teaching methods, rather than the implementation of STEM PBLs in the classroom. This prior work indicates a positive effect on STEM PBLs on interest, achievement, and attitudes, but the research did not focus on females or males in single-sex environments. This paper adds to the literature about understanding the effects of STEM PBL, building on enactivism and constructivism theories, by focusing on females and males in single-gender classrooms and mixed- gender classrooms. While our study had a small sample, making broad generalizations difficult, it provides a first look at this issue and requires further investigation. Researchers should continue exploring strategies that could close the gap between female and male interest in STEM careers, especially by providing informal learning experiences to females at an early age.

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