STEMing together: a comparison of co-ed and all-female informal learning environments

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Abstract

Purpose – Research has shown that science, technology, engineering and mathematics (STEM) self-beliefs and enjoyment are critical factors for predicting female students' persistence in STEM degrees and careers. Studies have shown the positive effects of informal STEM learning experiences on female students' self-beliefs. However, with the rise of all-female STEM learning experiences, such as summer camps, considering the potential advantages and disadvantages of co-ed options is important. Further, prior STEM education research has focused on sex differences in students' self-efficacy and STEM career interests. Our study aims to examine within sex differences in secondary, female students ($n = 104$) who attend either a co-ed STEM camp or a same-sex STEM camp.

Design/methodology/approach – To examine potential differences, we conducted independent sample *t*-tests.

Findings – Results of the study include statistically significant differences in mathematics and science self-efficacy as well as STEM career interest after participating in their respective camps.

Originality/value – Further, prior research in STEM education has focused on between sex differences in students' self-efficacy and STEM career interest.

Keywords Self-efficacy, STEM, Informal learning environment

Paper type Research paper

Introduction

Despite efforts to balance the science, technology, engineering and mathematics (STEM) career pipeline, the underrepresentation of women remains an issue (Martinez and Christnacht, 2021). For instance, in 2019, women accounted for 48% of the general workforce but only 27% of the STEM workforce in the United States (Martinez and Christnacht, 2021). This is concerning due to the missed perspectives and values that women could offer to these fields (Heybach and Pickup, 2017). The related phenomenon, known as the leaky STEM pipeline, has been associated with the manifestation of educational debt in the form of the identity gap, as female students, on average, develop lower STEM self-efficacy, not viewing

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themselves as members of the STEM community (Kang *et al.*, 2019; Nissen *et al.*, 2021). The identity gap is heavily influenced by the masculine stereotype of STEM, which frames males as inherently more capable of understanding and succeeding in STEM fields as females (Kombe *et al.*, 2019). Dismantling the masculine stereotype associated with STEM is critical to encouraging female students' STEM excitement and sustained engagement (Shairpo and Sax, 2011; Valenti *et al.*, 2016).

Additionally, students' mathematics and science self-beliefs have been identified as a filter for STEM career aspirations (Lofgran *et al.*, 2015; Toh and Watt, 2022; Watt *et al.*, 2017). Although 74% of female middle school students report interest in pursuing STEM careers, this percentage diminishes by high school (Maiorca *et al.*, 2021; Mazenko, 2016). Despite this, female students' STEM academic achievement is comparable to that of their male counterparts (Beekman and Ober, 2015; National Science Foundation, 2018; Ross *et al.*, 2012; Vela *et al.*, 2020; Watt *et al.*, 2017).

Existing research shows informal STEM learning experiences, such as after-school programs and summer camps, present promising avenues for strengthening female students' STEM self-concept (Chapman *et al.*, 2020; Maiorca *et al.*, 2021; Wieselmann *et al.*, 2020; Young *et al.*, 2017). Further, there is a movement in research and practice examining the potential benefits of same-sex educational experiences (Bigler *et al.*, 2014; Liben, 2015; Yabas *et al.*, 2022). To this end, we seek to examine the potential differences between gendered, informal learning environments and female students' mathematics self-efficacy, science self-efficacy and STEM career interest.

Literature review

Exposure to informal STEM experiences

In this study, we define informal learning experiences as any educational experiences that occur outside of the classroom (Vela *et al.*, 2020). These include activities such as after-school programs, field trips and summer camps, which provide opportunities to transform students' learning processes and understanding of concepts (Nite *et al.*, 2017). One primary mission of informal STEM learning experiences is to engage students as problem solvers and provide opportunities to build students' awareness of STEM fields (Roberts *et al.*, 2018). Additionally, due to their flexible nature, such experiences provide students with more immersive practices and robust knowledge of STEM disciplines and careers than formal instruction (Kwon *et al.*, 2021; Newell *et al.*, 2015; Popovic and Lederman, 2015). Short-term informal STEM learning experiences have been shown to support students' interest in persisting in STEM (Kitchen *et al.*, 2018).

Factors such as peer influences and individual beliefs are especially important for female students and impact their decision to participate in both formal and informal STEM activities (Vela *et al.*, 2020). However, informal STEM learning experiences that provide exposure to female role models and contextualized-applied learning positively affect female students' STEM sense of belonging and persistence (Bell *et al.*, 2017; Maiorca *et al.*, 2021; Young *et al.*, 2017). For instance, female students' coding identities – an especially underrepresented domain for women – can be cultivated through recognition from experts (Hughes *et al.*, 2021; Pinkard *et al.*, 2017). This corroborates findings of female students' increased dispositions towards STEM and positive identity development (Chapman *et al.*, 2020; Donmez, 2021; Kang *et al.*, 2019; Schilling and Pinnel, 2019). The flexibility of informal STEM learning environments affords time and space for students' divergent thinking and collaborative solutions. To this end, researchers found improvements in STEM perceptions after participating in a STEM summer camp (Kwon *et al.*, 2021). Thus, informal STEM learning experiences can provide benefits such as increased engagement, interest and positive identities.

Gender and STEM learning environments

Informal STEM learning environments have theoretical underpinnings in constructivism (Barak and Assal, 2018; Piaget, 2013) and social cognitive theory (Bandura, 1986; Nugent *et al.*, 2015). In these settings, students engage with authentic, challenging problems in teams to support campers' cognitive load and develop 21st-century skills such as collaboration, critical thinking and problem-solving (Voogt and Roblin, 2012). Thus, it is critical to consider the gendered nature and stereotypes historically surrounding STEM topics as campers engage in sociocultural co-construction of knowledge (Nissen *et al.*, 2021; Schnittka and Schnittka, 2016; Watt *et al.*, 2017).

Several existing studies examined the impact of co-ed versus same-sex formal and informal STEM experiences. For example, Iwuanyanwu (2022) found that female students in single-sex schools had higher attitudes toward science than their counterparts in coed schools. Schilling and Pinnel (2019) found that single-sex engineering camps had a greater positive effect on female campers' self-efficacy through activities allowing campers to take risks, such as project-based learning (PBL) tasks. Additionally, Schnittka and Schnittka's (2016) discourse analysis found that same-sex teams of females displayed the most group-oriented language solidarity, although females in co-ed teams made higher engineering post-test gains. However, there is a dearth of literature regarding direct comparisons between co-ed and same-sex informal STEM learning experiences.

Mathematics as a critical filter

Variables such as mathematics perception, mathematics self-beliefs, mathematics self-efficacy and mathematics anxiety are salient to students' persistence not only in mathematics classes but also in mathematics-intensive or associated careers (Jiang *et al.*, 2020; Kwon *et al.*, 2021; Watt *et al.*, 2017). For instance, seventh- and ninth-grade students with higher mathematical self-efficacy demonstrated statistically significantly higher knowledge of STEM careers (Blotnicky *et al.*, 2018). Similarly, middle school students' aspirations of becoming scientists can be predicted by self-reported creative tendencies varying in degree by biological sex and dispositions towards mathematics, science and engineering (Knezek, 2015). Specifically, mathematics self-concept or performance was especially important for female students regarding STEM career interests (Watt *et al.*, 2017). In terms of informal learning, researchers found an association between secondary students' mathematical problem-solving beliefs and changes in STEM career perceptions ($p < 0.05$) at a STEM summer camp (Kwon *et al.*, 2021). Due to the limited empirical evidence examining students' perceptions of mathematics and STEM careers in informal STEM learning environments, our study seeks to further analyze the relationship and determine if co-ed or same-gender environments act as moderators.

Historically, mathematics achievement has been viewed as a measure of innate ability. Sells (1980) described mathematics as a "critical filter" due to concerns regarding female students' low enrollment and achievement in advanced mathematics courses. Other researchers have stated that mathematics as a critical filter corresponds to perceptions of the field as a gatekeeper to high-status, high-income careers (Watt and Eccles, 2006; Watt *et al.*, 2017). Important to note is that the ratio of males to females at age 13 who score above a 700 on the Scholastic Aptitude Test (SAT) mathematics exam has changed from 13:1 to 3:1 between 1980 and 2010 (Benbow and Stanley, 1983; Brody and Mills, 2005; Halpern *et al.*, 2007). Additionally, the raw number of female students identified as mathematically gifted has increased (Hill *et al.*, 2010). Even still, research has demonstrated a persistent disparity between male and female students' perceptions of mathematics and mathematics self-beliefs (Gagnon and Sandoval, 2020; Hutchinson *et al.*, 2019). For instance, male students in second grade self-report positive mathematics self-beliefs prior to any performance differences from their female counterparts, who already demonstrate a decrease in mathematical self-belief as early as third grade (American Association of University Women, 2022).

Science and STEM persistence

Science and engineering are similar to mathematics in the importance of identity in pursuing these fields. First and foremost, authority figures' recognition of female students' abilities in STEM fields connects to the quality of their experiences (Calabrese Barton *et al.*, 2013; Tan *et al.*, 2013). Many students see science as a difficult subject (Archer *et al.*, 2010); however, due to lack of support or even dismissal from teachers, pursuing a career in science may seem especially unattainable to female students and those in underrepresented groups (Tan *et al.*, 2013). Furthermore, like math, students often believe that interest or ability in science is naturally determined (Archer *et al.*, 2010) rather than fostered. Researchers estimate that if more schools encouraged female students to study fields like science and engineering, the gender gap for students pursuing STEM post-secondary degrees could be reduced by 25% (Legewie and DiPrete, 2014).

There exists a need for an overall rebranding of how STEM content is portrayed to young learners. For example, to many, science is perceived as a masculine subject. This is true even in countries where there is overall gender equity or an equivalent number of males and females studying and working in science (Miller *et al.*, 2015). As early as elementary school, male students view themselves as more confident in their science abilities (Archer *et al.*, 2010; Redmond *et al.*, 2011). Similarly, by secondary school, many students perceive mathematics as more masculine than feminine (Brandell and Staberg, 2008). Furthermore, there exists a general disconnect between content offered in schools and "real" science (Archer *et al.*, 2010; Tan *et al.*, 2013) or mathematics (Garcia *et al.*, 2006), potentially impacting a student's decision to pursue STEM outside of school. A rebranding of science and engineering to include creative qualities such as artistic skills can potentially increase female interest in these subjects (Schilling and Pinnell, 2019; Tan *et al.*, 2013). Informal learning environments can help contribute to this notion of rebranding by providing students with female STEM role models, leadership opportunities (Redmond *et al.*, 2011) and creative outlets (Tan *et al.*, 2013).

Method

We examined the relationship between gendered, informal learning environments and female campers' mathematics and science self-efficacy and their interests in STEM careers by examining the following hypotheses:

H1. There is no difference between mean post-math self-efficacy for campers who attended co-ed and same-sex camps.

H2. There is no difference between mean post-science self-efficacy for campers who attended co-ed and same-sex camps.

H3. There is no difference between mean post-STEM career interest for campers who attended co-ed and same-sex STEM camps.

Participants and setting

This study took place at a STEM summer camp program at a large university in the southwestern United States in the summer of 2021 and the summer of 2022. We used a subset of data collected from $n = 8$ of the residential summer camps ($n = 6$ co-ed camps and $n = 2$ same-sex camps). Participants' biological sex was determined by camper enrollment, which was completed by the campers and their guardians. The same-sex camps were all female, with a mix of middle and high school campers. Two of the co-ed camps were solely dedicated to middle school campers, while four camps were designated for high school campers. Each co-ed camp had primarily male enrollment, with female campers making up less than a third of each camp's enrollment. Our study only used data collected from the female campers (Table 1).

Factor	Total	Percent (%)
N	104	
Year		
2021	56	54
2022	48	46
Camp		
Co-ed	48	46
Same-sex	56	54
Grade-level		
Middle school (Grades 6–8)	52	50
High school (Grades 9–12)	52	50

Source(s): Author's own work

Table 1. Demographics of study sample

Procedures

The residential summer camps were each one week long with the campers rooming with their same-sex peers. Individual camp sessions included both middle and high school students. Each residential camp provided immersive experiences and exposure to potential STEM careers through PBL, lab tours and panel sessions. Classes included basic coding, Python, chemistry, geology, entrepreneurship using a shark tank model, civil engineering through bridge building, rainforests with building a model crane for collecting data through a forest canopy, statistics, oceanography, engineering world challenges, programing microcontrollers, sewing wearable LEDs, cosmetic and food chemistry, egg drop, solar houses, designing roller coasters using principles of physics, trebuchets, banking and stock market trends, and thinking outside the box – designing furniture for rooms. Campers attended three courses per day on the university campus and toured university facilities with professors and their research teams. Panel sessions provided campers with direct access to STEM university students, researchers and professionals from a variety of careers (e.g. aerospace engineering, data science, oceanography). Representatives from the university, such as housing directors, financial aid office, admissions and academic advisors were invited to speak to the campers. Students also went on tours of various university plants (electrical, water, transportation and power), research centers (wind tunnel, vet med, engineering design center, nuclear engineering) and many other facilities. In the evenings, students would participate in games, sports, movies, swimming and bowling. On weekends, students visited local spaces like the animal park, aquatic center and entertainment center (arcade, mini-golf and laser tag). However, the same-sex, all-female camp immersed campers in an all-female camp environment explicitly with female instructors, counselors and panel discussants.

Measures

Researchers used the following scales to examine students' mathematics and science self-efficacy and their STEM career interests after participating in the summer camps. To collect data, researchers, with the assistance of camp counselors, circulated Quick Response (QR) codes to each camper to take online Qualtrics surveys on the first and last days of camp.

Student attitudes toward STEM. Campers responded to Faber *et al.*'s (2013) student attitudes toward STEM survey regarding their attitudes and self-beliefs toward STEM subjects. Students responded to prompts using a sliding scale from strongly disagree (zero) to strongly agree (100). We use a subset of the thirty-question survey to examine students' mathematics and science self-efficacy (Tables 2 and 3). In this study, math self-efficacy items had a reliability of $\alpha = 0.97$, and the science self-efficacy items had a reliability of $\alpha = 0.94$.

STEM career interest. Campers responded to Tyler-Wood *et al.*'s (2010) STEM career interest questionnaire regarding their intent to utilize their STEM knowledge and skills as well as their motivation and interest in pursuing a STEM career. To examine campers' STEM career interests, we use the questionnaire in Table 4. The campers used a sliding scale from strongly disagree (zero) to strongly agree (100) to respond to the prompts. In this study, the six items have a strong reliability of $\alpha = 0.90$.

Analysis

Before analyzing post-camp survey data, we compared pre-camp mathematics self-efficacy, science self-efficacy and STEM career interest using a two-independent sample *t*-test in STATA 18.0. No statistically significant differences in precamp survey results existed between participants attending the all-female and co-ed camps for the three outcomes of interest ($p > 0.05$). Therefore, we proceeded to test the hypotheses by comparing participants' post-mathematics self-efficacy, science self-efficacy, and STEM career interest across camp types (e.g. same-sex) using two-independent sample *t*-tests. Effect sizes for the *t*-tests were calculated using ω^2 due to the small sample size.

Table 2. Math self-efficacy for the student attitudes towards STEM survey

Item No.	Item
6	I am the type of student to do well in math
7	I am sure I could do advanced work in math
8	I can get good grades in math
9	I am good at math

Source(s): Items from Faber *et al.* (2013)

Table 3. Science self-efficacy for the student attitudes towards STEM survey

Item No.	Item
10	I am sure of myself when I do science
15	I know I can do well in science
18	I am sure I could do advanced work in science

Source(s): Items from Faber *et al.* (2013)

Table 4. STEM career interest for the STEM career interest questionnaire

Item No.	Item
1	I plan to use STEM knowledge/skills in my future career
2	I learned about new STEM knowledge/skills in camp that will help me in school next year
3	If I do well in STEM classes, it will help me in my future career
4	If I learn a lot about STEM, I will be able to pursue lots of different types of STEM careers
9	I am interested in careers that use STEM
10	Learning STEM in a school, classroom or activity (camp) motivated me to pursue a STEM career

Source(s): Items from Tyler-Woods *et al.* (2010)

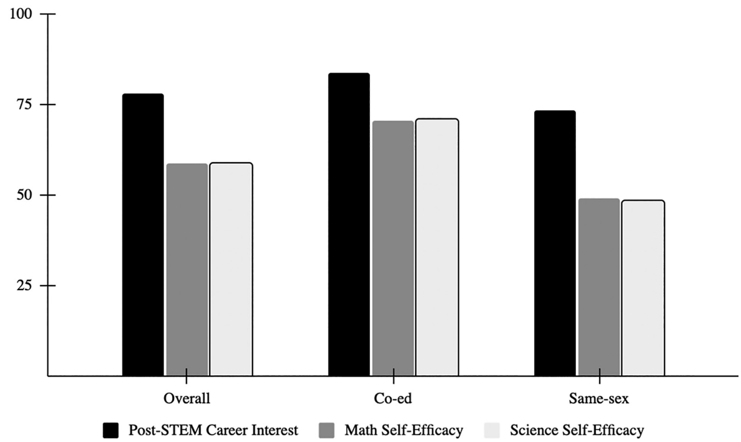
Findings

Our examination of middle and high school female students revealed that students who attended STEM camp overall reported moderate mathematics (M = 58.80, Standard Deviation *(SD)* = 38.50) and science (M = 58.60, SD = 36.50) self-efficacy on average. Despite reporting moderate mathematics and science self-efficacy across co-ed and same-sex camps, students reported high STEM career interest (M = 78.10, SD = 24.40). Figure 1 illustrates the comparison of mathematics and science self-efficacy and STEM career interest averages across and between camp types.

The results of our analysis indicated statistically significant differences between the camp types (Table 5). For Hypothesis 1, there was a statistically significant difference of 21.70 in mean mathematics self-efficacy between campers in co-ed and same-sex camps (df = 95, t = 2.864, 95% CI[0.51, 20.40]) post-STEM camp. In regard to campers' post-science self-efficacy, there was also a statistically significant difference (df = 95, t = 2.864, $p < 0.01$) between co-ed (M = 71, SD = 31.30) and same-sex (M = 48.30, SD = 37.50) camps. Furthermore, there was a statistically significant difference of 10.43 (df = 91, t = 2.087, 95% CI[0.51, 20.40]) in post-STEM career interest between co-ed and same-sex camps.

Discussion

The leaky STEM pipeline is associated with females' low self-esteem in STEM, or the identity gap. The identity gap contributes to the masculine stereotype of STEM fields (Kang *et al.*, 2019; Nissen *et al.*, 2021). As educators seek to address this critical issue, it is paramount to continue examining the effect of gendered learning environments in STEM fields and its potential impact on the identity gap. In this study, we specifically examine middle and high school students' mathematics and science self-efficacy as well as interest in STEM careers due to the significant influence these factors have on female students' persistence in STEM education through advanced courses, pursuing STEM degrees and pursuing STEM careers after university (Bell *et al.*, 2017; Jiang *et al.*, 2020; Kwon *et al.*, 2021; Maiorca *et al.*, 2021). Furthermore, factors such as peer influences and individual beliefs are salient to female students' STEM disposition and their decision to participate in STEM activities (Vela *et al.*, 2020). To this end, we investigated potential differences in student outcomes in all female and co-ed STEM camps.



Source(s): Authors' own work

Figure 1.
Bar graph of averages overall and across camp type

Table 5. Two-tailed independent sample *t*-test results

	Co-eD			Same-sex							95% CI		
	N	M	SD	N	M	SD	df	Δ M	Δ SE	t-score	LL	UL	ω^2
Post-STEM career interest	42	83.80	22.00	51	73.40	25.50	91	10.43	5.00	2.087*	0.51	20.40	0.04
Mathematics self-efficacy	44	70.60	34.30	53	48.90	39.40	95	21.70	7.58	2.864**	6.66	36.70	0.07
Science self-efficacy	44	71.00	31.30	53	48.30	37.50	95	22.71	7.11	3.195**	8.60	36.80	0.09

Note(s): ***$p < 0.001$, **$p < 0.01$, and *$p < 0.05$
Source(s): Author's own work

Providing female students with opportunities to experience STEM learning has shown promise in strengthening women in STEM self-concept which has been shown to improve STEM persistence (Chapman *et al.*, 2020; Maiorca *et al.*, 2021; Wieselmann *et al.*, 2020; Young *et al.*, 2017). These experiences are also essential in increasing female student's engagement in STEM fields as well as working towards mitigating the historical effects of the masculine stereotype in STEM fields. The present study examined the relationship between informal STEM learning environments and female students' mathematics self-efficacy, science self-efficacy and STEM career interest.

We analyzed three hypotheses to examine the relationship between gendered informal learning environments and female campers' mathematics and science self-efficacy and their interests in STEM careers. In addressing Hypothesis 1, stating there is no difference between mean post-science self-efficacy for campers who attended co-ed and same-sex camps, the results of this study supported rejecting the hypothesis due to a statistically significant difference between co-ed and same-sex camps. Interestingly, despite the same-sex camps providing female students with a plethora of STEM role models and creative science opportunities in an all-female environment, female students who attended the co-ed camp reported a higher science self-efficacy. Similarly, the analysis for Hypothesis 2 comparing post-mathematics self-efficacy between same-sex and co-ed camps also showed a statistically significant difference. Our analyses focused on differences between female students' outcomes; however, prior research has shown higher confidence in science (Archer *et al.*, 2010; Redmond *et al.*, 2011) and mathematics self-efficacy (American Association of University Women, 2022; Gagnon and Sandoval, 2020; Hutchinson *et al.*, 2019) for male students. Further investigation of the interpersonal experiences in the same-sex and co-ed STEM camps which inform students' self-efficacy.

Of note, our findings indicate that despite differences in science and mathematics self-efficacy, both groups of female students reported high (statistically significantly different) STEM career interests after participating in their respective camps. Contrasting to traditional schooling, informal STEM learning experiences such as summer camps provide students with the opportunity for deeper, sustained inquiry and diverse, hands-on exposure to STEM disciplines and careers (Kwon *et al.*, 2021). The results from our study further support Kwon *et al.* (2021) due to the high interest that students express in STEM careers after exposure to STEM role models and mentors from various careers.

Conclusion

Despite the closing achievement gap between female and male students in STEM, attending to students' STEM self-beliefs and enjoyment is critical to address female students' persistence into STEM degrees and careers. Prior research has shown the positive effects of informal STEM learning experiences on female students' self-beliefs (Young *et al.*, 2017). However, with the rise of all-female STEM learning experiences such as camps, considering the potential advantages and disadvantages to co-ed options is of importance. Although our study includes a small, niche sample of female students who chose to spend time out of their summer at an educational camp, it provides a description of the differences in student outcomes. Our results indicate statistically significant differences in mathematics and science self-efficacy and STEM career interest between female students who participated in co-ed and same-sex residential STEM camps. This result highlights the gendered dynamics of informal STEM learning and potential differences in the effects of learning environments.

While there is a dearth of literature that specifically compares co-ed and same-sex informal STEM learning experiences, our results are aligned with the previous studies attributing the positive effects on self-efficacy of female campers when engaging in informal STEM experiences (Schilling and Pinnel, 2019). Our study contributes to the literature by highlighting, with sex variation in mathematics self-efficacy between STEM camp typestype (i.e. same sex, co-ed). Future research may examine students' rationale for choice of informal STEM learning environment to help explain differences in student outcomes. For instance, investigating whether female students who are more reticent in STEM select all-female learning experiences may be a critical factor for nurturing their self-beliefs over an extended period of time.

Due to our limited sample, further research is required to comprehensively analyze student outcomes for gendered informal STEM learning experiences. Moreover, future research may examine female students in same-sex and co-ed informal STEM learning environments longitudinally. This study utilizes data from weeklong residential camps. Investigating differences in self-efficacy and STEM career interest over a longer period of sustained engagement with the learning environment may yield more comprehensive results to inform efforts to retain female students in STEM. Furthermore, capturing qualitative data such as student interviews and reflections would help explain the influence of all female and co-ed STEM learning experiences. Finally, examining the intersectionality of other student characteristics such as race, socioeconomic status, and prior STEM achievement in combination with the same-sex and co-ed learning environments would help provide nuance to the complexity of supporting female student persistence in STEM fields.

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Further reading

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