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The Role of All-Female STEM Spaces in Encouraging High School Girls to Pursue STEM (Fundamental, Diversity)

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Abstract

The numbers of women in science, engineering, computer science and mathematics professions continue to be low despite decades of interventional efforts. Much research has focused on interventions at the middle school level or retention at the university level. Yet some research suggests it is girls' identification with a science or STEM domain during the pre-college years that is one of the strongest predictors of intent to pursue or persist in a STEM major in college.

This exploratory case study examined the lived experiences of eight high school girls who exhibited strong STEM identities. This work reports on the role that all-female STEM spaces influenced participants' intent to pursue STEM majors in college. Eight junior and senior girls were interviewed over the course of an eight-week period during fall 2019 regarding their perceived feelings of self-efficacy, their feelings of recognition in STEM, and their interest in STEM domains. This qualitative research was framed using Godwin's 2016 Engineering Identity Framework, adapting it to accommodate a broader STEM Identity and replacing Godwin's performance/competence belief construct with the well-defined construct of self-efficacy. Domain-specific identity can be defined as "being recognized as a 'certain kind of person' in a given context" and is only one part of one's overall identity. The STEM Identity Framework was defined as a combination of self-efficacy beliefs and feelings of recognition and interest in STEM. Research indicates that domain-specific identity is a predictor of recruitment and retention of students to those fields.

This research suggests that all-girls spaces such as extracurricular STEM clubs for girls reinforce recognition and support the development of STEM identity in high school girls. Girls developed feelings of belonging in STEM which, research shows, lead to motivation, engagement, increased academic performance and increased intent to persevere in STEM fields. Further, girls' experiences in all-girl STEM clubs allowed them to feel a degree of immunity to the negative effects of gender bias.

The implications of this study lead to practical recommendations for high school teachers, administrators and pre-service teacher education programs. Schools committed to closing the gender gap in STEM fields are recommended to develop all-girl clubs, such as Girls in STEM or Girls Who Code, that promote a sense of belonging and validate their feelings of competence and recognition in STEM domains.

Introduction

It is well established that the gender gap in engineering and computer science in the US is large and persistent. Women are needed in STEM, not only to grow a qualified workforce to meet future economic needs, but also because their contribution to innovation can help design a future for our country that will better serve the needs of all its citizens. There is an abundance of literature on the gender gap in STEM, which attempts to identify causes of this gap and to uncover effective interventional strategies. Much research is focused on external factors and

how these impact girls' self-efficacy such as gender stereotypes, gender bias, and perceptions of engineering and computer science, as well as on internal factors such as student mindset and interest level [1] - [6]. A subset of the research focuses on discipline-specific identity and how it can impact career choice [7] - [10]. It is difficult for adolescent girls to forge a STEM identity in a social environment in which they are being exposed to negative stereotypes potentially from teachers, family, friends and peers [11], [12]. Yet, some girls are able to demonstrate resilience toward exposure to gender stereotypes and gender bias in STEM.

The goal of this study was to identify the factors that enabled girls to develop strong STEM identities in high school despite exposure to stereotypes and gender bias. The questions of practice which guided this study arose from a relative lack of understanding about the ways in which girls develop a STEM identity. The intent of this study was to uncover factors that enable certain girls to develop strong STEM identities in high school despite exposure to gender stereotypes and bias in STEM domains. Their counternarratives provide, "new windows into the reality of those on the margins allowing new and different possibilities to be showcased, and by combining elements of the story and the current reality, thus constructing another world that is richer than either story or reality alone" [13]. This study investigated the research questions:

1. In what ways do extracurricular STEM clubs motivate girls to identify as a "STEM person?"
2. How do girls negotiate their recognition, self-efficacy and interest within the STEM disciplines?

Conceptual Framework

Gee [13] defines identity as "being recognized as a certain 'kind of person,' in a given context." A student's domain-specific identity occupies only a portion of his or her overall identity. In this study I draw on the domain-specific identity framework developed by Carlone and Johnson [15] who first visualized science identity as a function of the three constructs of competence, performance and recognition. Domain-specific identity was expanded on by Hazari, Sonnert, Sadler and Shanahan [16] to include student interest. Performance and competence are difficult to measure, however, because, as Godwin [17] noted, undergraduate students are unable to distinguish between competence beliefs and performance beliefs. She consequently combined these two constructs into performance/competence. This framework for measuring identity beliefs has subsequently been implemented in physics, engineering and mathematics identity research [18], [19]. In this study, I used an adaptation of Godwin's Engineering Identity Framework with two important modifications (Figure 1).

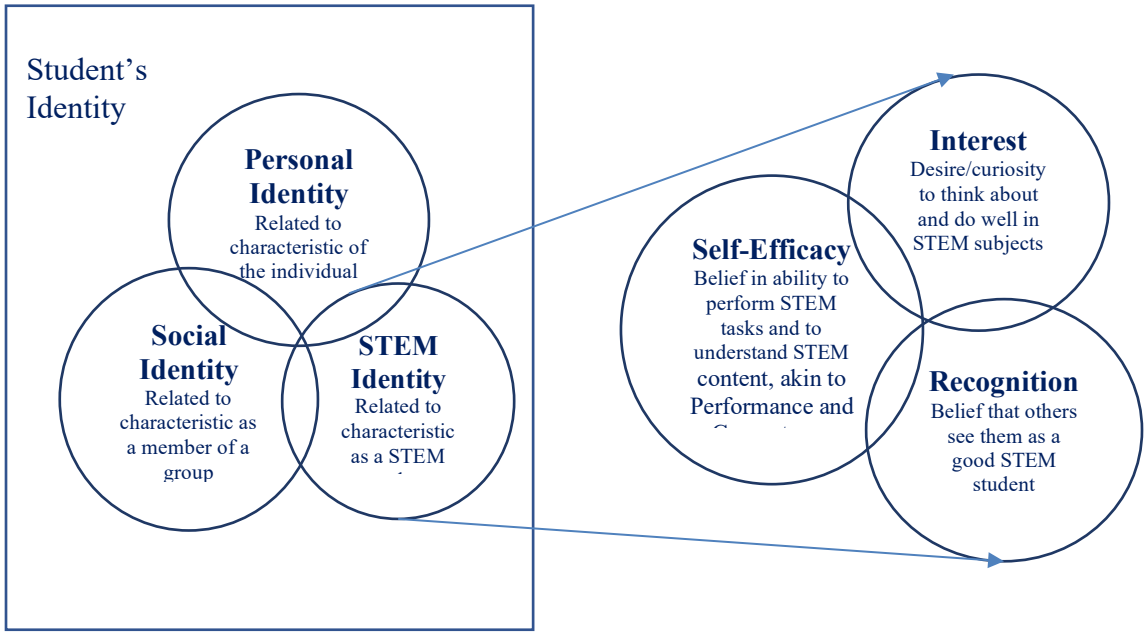

Figure 1. STEM Identity Framework for students' identification with engineering, adapted from Godwin, 2016.

First, to understand self-perceptions in several STEM disciplines, I utilized "STEM identity" as a broader construct to capture all the domain-specific identities particular to the subjects. While the eight girls in this study were developing skills and interests in a variety of male-dominated STEM fields (engineering, computer science, architecture, medicine), they experienced challenges common to building identities in the face of stereotypes and gender biases. Therefore, the use of "STEM identity" is consistent with representing their varied but similar identity development experiences. Second, I utilized the construct of self-efficacy as a proxy for competence/performance, since it is broadly represented in research into the STEM gender gap and is inextricably tied to the creation of science identity [20]. Self efficacy strongly predicts academic performance, choice of college degree, and persistence along that career path [1], [6], [21].

Methods

This study aimed to collect qualitative data on high school junior and senior girls related to the development of their STEM identities. I explored the lived experiences of these girls as they defied gender stereotypes and created a STEM-specific identity, through interviews, focus groups and observations in a fine-grained, qualitative analysis. Participants who satisfied each of the following criteria were sought: a) an 11^{th}-12^{th} grade girl, who b) was actively participating in a STEM club and c) identified as a "STEM person."

The study examined a purposeful sampling of eight high school girls who self-identified as having a strong STEM identity. All eight participants responded positively to the prompt "Do you identify as a STEM person?" No context or explanation of that term was provided; each of the participants' definitions of what it meant to be a STEM person was extracted during the interview process. The participants were also active members of extracurricular STEM clubs including the Girls in STEM, Girls Who Code, Rocketry and Engineering clubs. Of the eight girls, three were Hispanic, three were White, one was Black and one Asian.

The goal of this case study was to identify factors that influence girls' identities in STEM disciplines, and how these identities are negotiated. This research study followed an exploratory case study design, an in-depth examination of a 'bounded system' based on a variety of qualitative data collection materials [22]. Qualitative data were collected through a variety of instruments and were triangulated during analysis. Data collection instruments included fifteen semi-structured, individual interviews, three focus group discussions, six observations during club activities and a sampling of artifacts. The qualitative data were coded according to Saldaña [23], and the data were analyzed to construct themes and make assertions.

Table 1. Semi-structured interview and focus group sample questions.

Data collection instrument	Sample Questions
Semi-structured Interviews	● What do you like about science, math or STEM? ● What kind of job do you see yourself doing after college? ● Have you participated in any other STEM-related programs in high school? ● Was there a particular moment that stands out for you when you decided that STEM was the right domain for you? ● Have you participated in math- and science-focused after school programs or camp activities before?
Semi-structured Focus Groups	● Do you see yourself as an engineering/computer science person? ● Do your teachers see you as an engineer/computer scientist? How do you know? ● Do you enjoy learning engineering/computer science? ● Are you interested in learning more about engineering/computer science? ● Are you confident that you can understand engineering/computer science? ● Do others ask you for help in this subject?

Qualitative data were analyzed iteratively over the course of the data collection period. All data were coded by the researcher using a combination of *a priori* and initial coding methodologies.

The *a priori* or pre-determined codes were based on the theoretical identity framework, created to help align data coding with the research questions. Initial or open coding, on the other hand, is aligned with grounded theory of qualitative data analysis [23]. Grounded theory is a methodology for qualitative data analysis that is 'grounded' in the data, such that the theory develops concurrently with data collection from a constant comparative analysis of the data [24]. The data were systematically analyzed according to grounded theory using initial, open coding methods as outlined in Saldaña [23].

Data & Analysis

Qualitative data were analyzed concurrent with and following the data collection window, and three themes emerged from the data. Themes address the ways in which extracurricular STEM clubs influence identity development (Research Question 1), and the processes by which girls negotiate these identities (Research Question 2). Themes were validated by participants through member checking during second interviews.

All eight participants spoke about the significance of having a community of like-minded girls as part of their identification with STEM. Codes that represented this theme included the process codes "belonging to a group," "working with others," "supporting or being supported," and the descriptive codes "girls in STEM" and "club." As the data associated with these codes were compared and analyzed, several theme-related components emerged. These included a) all-girl communities create a safe space free from gender bias, b) all-girl communities create a sense of belonging, and c) all-girl communities are a place where girls actively support one another academically and emotionally.

Theme one: All-girl communities create a safe space, free from gender bias. Part of the struggle for girls pursuing STEM courses in high school is the lack of peers in STEM classes, particularly computer science and engineering. Participants expressed feelings of anxiety with regard to being in a majority- or all-male classroom, and the presence of other females reduces that anxiety. Caroline, in taking a summer coding course, said:

> I got really scared because all of the other people in my class seem to have like done coding before, they did stuff at home that was extra because they were so confident in it and it was kind of scary, but overall I got through, my teacher was a woman too and she talked about her experience and working decades ago when she started the industry and how it was a predominantly male and I think that helped me. But that was that's kind of scary.

Participants were less likely to engage in content discussions in male-dominated classes, particularly when they are unsure about a topic. Anna said, "I feel like less comfortable saying, you know, speaking out or yeah, like speaking out on something if I don't understand." This is in contrast, or in response, to the confidence that participants saw from male peers.

In describing the feeling of being the only girl in a classroom of boys, gender bias could manifest as feeling excluded. Simone referred to feeling "out of place," saying, "It almost feels like you're not supposed to be there because everyone doesn't look like you." In discussing feelings associated with being a minority within a STEM class, the participants all asserted they felt as competent as the boys in these scenarios, equally able to complete the tasks assigned and to understand the course material. An exchange during one of the focus groups that was met with universal agreement showed this confidence:

> Julia: I don't think they realize how smart we are.
> Anna: That's so true [laughs and giggles]
> Julia: [They are] like, "Oh she doesn't know." But little do they know, *we know*. Yeah.

The girls in this study experienced feelings of competence in science, however these feelings did not translate into an experience of belonging in the STEM community within their classes. In contrast, when being in an all-girl space, participants felt "it's easier to voice like when you don't understand something." Participants had difficulty articulating exactly what about the all-girl community was less daunting, using words such as "more productive," "relaxing," and "more comfortable." In focus group one, participants talked about other girls understanding "the struggles" they experience in the engineering and STEM domains. While the participants were not able to articulate the nature of the struggle or the feelings of judgement or bias within a male-dominated STEM environment, when brought up within focus groups the other participants actively nodded and verbally agreed, underscoring these feelings. One participant, Julia, gave her perspective of the gender bias she feels when she noted the lack of female engineers in her own family:

> I just think that like it's kind of like in our nation's like culture. Or in a way like, like in like the 50's or 60's or whatever. It was like in history like the women were the ones that just like stayed home and like the men were the ones out working like my, all my like my grandparents were engineers like my mom's cousins were engineers. The uncles are engineers, like none of my mom's sisters are engineers. None of my grandma's were engineers. And so I don't know. I think it's just kind of like rooted in like the culture and like it's hard for people to kind of see change. And like see things happen. Like I don't know. It's just like hard for some people to think of like women as engineers and like I get it because like it is like kind of how the culture is and like you really can't like you can change culture but it's a lot harder to change people's views after things have been like that for so long.

Membership in the all-girls clubs created a space in which girls were protected from the gender-biased messages that they were receiving in their classes and their families.

Theme two: All-girl communities create a sense of belonging. The girls struggled with the challenge of belonging as a STEM practitioner. In this study, Eleanor spoke about negotiating

her desire to join a co-ed STEM club and the challenge of feeling unwelcome in the club community:

> I went to TSA [club], yeah, it was all guys like there weren't any girls in it and like these like super geeky smart guys, like you would like stereotypically find like in that kind of club like a technology club, and that's kind of off-putting for someone who's like… like, when I joined it, I didn't know much of anything. I just wanted to make stuff and I [had] no idea what I was doing. I was also the only girl and they weren't my friends like I didn't know them and that was actually… I didn't… I joined the club then I didn't go the rest of the year.

When Eleanor joined the following year, it was easier for her as there were other girls who had also joined, and the club seemed less "cliquish." She said she "felt really bad that I kind of left" the first year, and went on to say she "didn't want to tell them that I felt unwelcomed, right? So I just said I was too busy." This push-and-pull experience of wanting to participate but not being able to become a part of the club exposed Eleanor's struggle to fit in to the local STEM community and further develop her STEM identity.

Coincidentally, all eight participants belonged to an all-girl STEM club, either Girls in STEM or Girls Who Code, and four of them also belonged to co-ed STEM clubs such as Rocketry or Engineering in addition. The feeling of community and unity within the all-girl clubs was described as stronger than in other clubs. Avery stated:

> I feel like the community like basis of like the more girl-centered club is like a lot stronger and that we kind of like understand more like the struggles especially like in like the fields that the clubs are like designated like we kind of understand those like struggles a little better and I just feel like overall like, I don't know like it's really hard to explain. I just feel like the it's like more productive way to like have just like a community of just girls working towards a common goal.

Julia, who was confident in her choice to pursue a career in Industrial Engineering, said about having an all-girl STEM community in high school, "I think it's super, *super* like encouraging and supportive. I don't know if I would be so, I guess, determined if I didn't have that kind of environment."

The existence of the Girls in STEM club and Girls Who Code club attracted girls who were not interested in similar clubs that included both boys and girls. Eleanor stated:

> I joined the girls in STEM club because like it was only for girls and like I kind of want to like [have] a sense of community with only girls who are also interested in the same things as me.

When describing all-girl spaces in STEM, particularly within clubs, participants in this study

expressed feelings of support and a sense of validation. Participants describe the all-girl club environment as "hanging out with friends." Girls either join clubs with existing friends or they join the clubs and make friends, extending their female friend groups to include "girls who are also interested in the same things as me."

Theme three: All-girl STEM communities are a place where girls actively support one another academically and emotionally. Being in the Girls in STEM club, participants knew several other girls who were taking or who had taken engineering electives. This gave them the sense that taking the class was manageable. Caroline expressed feelings of being supported in the all-girl club, saying,

> [This] community enables me to feel like, like I'm a part of something and then when I wanted to go forth and, like try harder classes or join a club I feel okay because there are other people supporting me with similar interests.

During club meetings, girls were observed to have helped each other with challenging coursework such as AP Calculus. During activities, casual conversations were also a way in which girls would support one another. Avery, in supporting another club member, was heard saying, "...so like if you fail it's not like...," while discussing experiences of academic adversity in a STEM course. Clubs provided the time and space to support one another emotionally, to have conversations about STEM classes and feelings of vulnerability. Clubs also provided girls the ability to engage with one another on academic concepts and to ask for and give help.

Results & Findings

The purpose of this study was to identify what activities, interactions and experiences within the all-girl STEM club space contributed to the development of STEM identity for eight high school girls, and through what processes this identity was negotiated.

In addressing Research Question 1, "In what ways do extracurricular STEM clubs motivate girls to identify as a 'STEM person?,'" this study identified three themes through which all-girl STEM clubs contribute to girls' identification with STEM fields: a) all-girl communities create a safe space free from gender bias, b) all-girl communities create a sense of belonging, and c) all-girl communities are a place where girls actively support one another academically and emotionally. These themes were derived from interactions, activities and experiences within the high school environment that contributed to identification with STEM and identity-building.

First, girls in this study experienced a sense of belonging within all-girl STEM club communities. Belonging, in this context, is defined as, "the extent to which students subjectively perceive that they are valued, accepted, and legitimate members in their academic domain" [25]. Peers who themselves value, support and succeed in STEM fields promote a sense of belonging in STEM for others [26], [27]. This sense of belonging is associated with a strong sense of STEM identity [28] and with persistence in STEM [25], [28], [29]. Belonging to a STEM

community is more impactful for women than for men when predicting persistence [29], possibly due to the existence of negative gender role biases to which women are continually exposed. For these reasons, belonging to a STEM community can work to counteract negative influences of gender biased peers, and positively impact the development of STEM-based occupational identity [27]. In addition, students who experience belonging in STEM are more motivated, more engaged, and demonstrate increased academic performance and intent to persevere in STEM fields [12], [30]. Taken as a whole, this body of evidence strongly underscores the importance of the STEM community and local environment in which girls participate in high school.

Next, discourse with like-minded peers about one's interest in STEM creates social recognition and reinforces interest development, particularly for girls [29]. Their research suggests that discussing emerging interests is an important social process for negotiating whether the new interest is recognized and accepted by others. When girls talk about their interest in STEM, they observe the reactions of their peers, and gain recognition when those reactions are encouraging and understanding. These validate the assertion that vicarious experiences and social recognition development are part of the process of negotiating one's STEM identity. The all-girl clubs in the current study provided repeated opportunity for girls to negotiate their identities through informal discourse.

Lastly, friends are an important source of support particularly for girls developing an identity in STEM domains [32]. The overlap of a student's social and STEM identity domains that happens in the all-girl clubs may strengthen the effect of identity-building. As noted by Riegle-Crumb et al. [33], "The nexus of the social and the academic—of friends with academic colleagues—in a mostly female context may be particularly valuable for girls' pursuit of advanced studies in math and science." Girls' discussions tend to be more personal and include more discussion of identity and disclosure of information than boys' [33] which can lead to the inclusion of social identity development adjacent to and overlapping with STEM identity development. In addition, friends' and classmates' academic success in math has strong association with adolescent math course-taking, particularly for girls [33]. Personal relationships that girls establish with other females who are proficient in science and math create a unique social and academic context that enable a personal STEM-identity to emerge. It follows that simply keeping company with academically-focused, high achieving girls can thereby influence STEM identity-building. Female friends who are academically successful can be considered, "a tangible resource on which girls can draw to push forward in subjects that are stereotyped as male and in which women have been historically underrepresented." [33]. It may even be that the performance of STEM-related activities in the clubs is secondary to the social value of belonging to the community of STEM-identifying fellow girls [34].

Consistent with the framework of STEM identity based on Godwin [17], development of all three components of domain-specific identity was also evident, addressing Research Question 2, "How do girls negotiate their recognition, self-efficacy and interest within the STEM

disciplines?"

Recognition. Girls negotiated their identity through self-recognition and through experiencing social recognition from others. The importance of recognition to identity development is clear, as identity was previously defined as being "recognized as a 'certain kind of person'" [14]. Social recognition in this context refers to the recognition that a girl is a participant in a STEM domain. These forms of social persuasion can be verbal messages of encouragement, recognition of academic strengths, and/or being seen as a "STEM person." Recognition can also be internal, referring to the way in which a girl considers herself a "STEM person." Recognition of others can lead to self-recognition as girls rely on and internalize messages from significant others, as they begin to see themselves as a "STEM person." This social recognition is particularly important for girls, who are significantly more apt to be influenced by social messages and verbal persuasions [6], [35]. Girls and young women rely on the judgements of others to create their own self-efficacy beliefs – it is important to them that others believe in them [6], [21].

In this study, social recognition played an important role in the girls' identity development. Girls felt recognized by others in their clubs as being a valuable member and contributor to projects and activities. They felt that younger club members and students not in the club saw them as someone to look up to, as competent, and as science people. This is in line with the findings of Carlone and Johnson [15] who asserted that recognition is a key influencer of students' identities. This result is also in line with research that suggests exposure to confident female peers results in higher levels of intent to pursue STEM disciplines [36].

Self-efficacy. Self-efficacy beliefs powerfully impact achievement and are a central component of domain-specific identity. The extent to which one believes in one's ability to succeed is prerequisite to effort, perseverance and resilience [1], [21]. Girls in this study spoke of the value of academic challenge and the experience of being good at science, technology and/or mathematics, revealing the strength of their own self-efficacy beliefs. Indeed, the STEM experiences they chose to share were not always those of academic success. They often spoke about intent to persevere despite failures, which is an indicator of strong self-efficacy [37] and of possessing a growth mindset [3]. The girls in this study developed this self-efficacy in STEM domains predominantly through the experiences of recognition and belonging.

Self-efficacy in STEM is also supported by feelings of belonging to a STEM community. Girls in this study developed feelings of belonging and connectedness in STEM through participation in all-girl clubs. Belonging is directly correlated with self-efficacy, as students high in sense of belonging show better performance, motivation, engagement and intention to persist.

Interest. Spending time with peers who support and scaffold interest in STEM was an influencer of STEM identity in this study. Observing peers inhabit a 'STEM identity' and perform well in STEM disciplines is a form of vicarious experience, which supports self-efficacy

development [1]. The results of this study also align with empirical evidence from Jackson, Leal, Zambrano and Thoman [31] who found that talking with like-minded peers about one's interest in STEM creates social recognition for girls, resulting in interest development. Their research suggests that discussing emerging interests is an important social process for negotiating whether the new interest is recognized and accepted by others. When girls talk about their interest in STEM, they observe the reactions of their peers, and gain recognition when those reactions are encouraging and understanding. This validates the assertion that vicarious experiences and social recognition development are part of the process of negotiating one's STEM identity. The all-girl clubs in the current study provided repeated opportunities for girls to negotiate their identities through informal discourse.

Significance of Findings

There is ample research on single-sex educational spaces as a means of attracting and retaining girls in STEM disciplines, but there is a lack of consensus as to their efficacy. These studies are all founded on the hypothesis that mixed-gender education, formal or informal, can serve to reinforce existing gender stereotypes for girls in STEM. However, there is a broad range of findings, possibly due to the variety of programs considered as all-girls education in STEM. Studies include single-sex STEM education in high schools [38] - [41], middle schools [42], informal STEM educational programs [19], [43] - [45], university courses [46], [47] and living-learning communities [48]. Some research finds no evidence of improved outcomes for girls and women, other research suggests that there is a benefit, but the mechanisms by which this benefit occurs are often unclear.

The current study adds to the body of research in support of single-sex spaces for girls, adding qualitative data in the form of authentic student voices. The results support the theory that participating in an all-girl STEM environment can provide STEM-identity-building opportunities that are not conferred in regular mixed-gender spaces. The data suggest it is the all-girl extracurricular space, rather than the mixed-gender classrooms or clubs, in which these experiences take place. This is consistent with research that highlights how important single-sex experiences can be for fostering girls' interest in engineering fields [17], [19], [34], [42], [44], [49], [50]. Whereas single-sex STEM classrooms are not common within mixed-gender high schools, the less-formal extracurricular club environment can allow for all-girl STEM communities to develop and thrive. These clubs may in fact be considered primarily identity-building spaces for girls, independent of their level of engagement in STEM activities [34].

Extracurricular, all-girl STEM clubs and communities are recommended for the development of STEM identity in high school girls. In particular, clubs that maintain a focus on community-building and social recognition, and where STEM activities are viewed as a catalyst for strengthening self-efficacy and interest. Considering the impact of single-sex clubs on female self-identification in STEM subjects, broad adoption all-girl STEM communities at the secondary education level could embolden many future generations of female engineers and

computer scientists and help to close the gender gap in STEM fields. As STEM identity is still a relatively new construct in academic literature, further research into the mechanisms through which STEM identity is developed is warranted. In addition, further research could examine the individual ways in which STEM identity emergence intersects with ethnic identity development in underrepresented minority groups in STEM.

Limitations

This exploratory case study has limitations, the most significant of which was the nature of the case study itself. A case study is intrinsically small and heavily descriptive. This study featured only eight participants, and thus did not aim to create findings representative of the entire population of MHS girls or of high school girls in general. The aim of this research was to identify factors contributing to the development of a positive STEM identity, and to observe the ways in which girls negotiated their STEM identity. Thus, a small case size suited the nature of this research. Secondly, there is an inherent limitation in measuring STEM identity, which in itself is a complex construct with no universally accepted definition in the scientific literature. It is important to note that identity development also is an ongoing process and for teenage participants in particular, identity can be assumed to be in flux. Lastly, the gender-focused nature of this study leaves unaddressed the experiences of gender non-binary participants who might offer additional insights into STEM identity development in underrepresented high school students.