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The Role of STEM Self-Efficacy on STEM Identity for Middle School Girls after Participation in a Single-Sex Informal STEM Education Program

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ABSTRACT

Science, technology, engineering, and mathematics (STEM) careers are some of the highest paying options for students today. In addition, nations with strong STEM workforces and research capabilities are more competitive in the global market. One way to improve the number of people working in STEM is to improve the representation of underrepresented groups, like women, in these fields. Research demonstrates that for girls and women to persist, they must identify with their STEM career of interest which can be difficult for fields that have been historically, and remain, dominated by men. This study focuses on the role that an informal STEM education camp in the United States has on middle school girls' STEM identity. The authors conducted a linear regression and hierarchical linear modelling analysis to determine the role that the program had on 145 female participants. The results indicate that a crucial component to STEM identity is girls' levels of *openness to challenge.* The study indicates that informal STEM education programs should provide students with chances to be challenged in a way where they see these challenges as opportunities to grow rather than opportunities to fail.

KEYWORDS

Identity, Self-efficacy, Gender, Informal STEM Education

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INTRODUCTION

Being a member of the science, technology, engineering, and mathematics (STEM) workforce has both individual benefits for those who work in these fields as well as group benefits for the nations who employ them. First, STEM careers are some of the highest paying salary options for people today (Lacey & Wright, 2009). Second, those nations with strong STEM workforces and research capabilities are more competitive on the global market (Gates, Mundie, & Schaal, 2014; The Jobs Council, 2011). Consequently, over the last decade, the United States (U.S.) government and other U.S. organizations have focused on the importance of building a larger workforce within STEM fields (Committee on STEM Education of the National Science and Technology Council, 2018; President's Council of Advisors on Science and Technology [PCAST], 2012; Lacey & Wright, 2009). A report compiled by the President's Council of Advisors on Science and Technology (PCAST, 2012) under President Obama, projected that the U.S. will need an additional one million STEM college graduates over the next decade to remain competitive as a nation. One of the potential solutions is to increase the number of women and underrepresented minority groups (identified as African Americans/Blacks, Hispanics/Latinos, and Native American/American Indians) in these fields. These underrepresented groups (URGs) are increasing in the general U.S. population, but not in the STEM workforce. For example, according to the U.S. Census Bureau (2010) URGs currently represent 30% of the U.S. population (and are predicted to represent 45% of the population in 2050), but only 9% of the current STEM workforce. Women represent 50% of the U.S. population but closer to 35% of the STEM workforce (National Science Foundation [NSF], 2017). If the US is to remain competitive in a global marketplace then it must cultivate and retain more young people in STEM fields, particularly those from underrepresented groups.

STEM persistence research focuses on key transition points wherein individuals – particularly women and URGs – are lost in the STEM pipeline. Middle school (ages 10-14) is a key transition point because this is where students begin to lose interest in STEM and this interest is a prime indicator of STEM persistence (Archer et al., 2012; Poirier et al., 2009; Tai et al., 2006). This transition point is compounded by the fact that if a student loses interest at this age it becomes more difficult for them to re-enter the STEM pipeline later because they will not have taken the requisite and sequential classes, making re-entry time consuming and difficult. Race, gender, and income play a role at this age as well, since this is the age where students begin to experience the effects of stereotypes, often perceiving STEM fields as limited to middle-class, white males (Aschbacher et al., 2010; Carlone, 2003; National Research Council [NRC], 2011; Polman and Miller, 2010). Studies show that science as it is taught within the formal classroom structure tends to perpetuate these stereotypes while also ignoring the relevance of STEM fields to non-majority students' lives (Aschbacher et al., 2010; Brickhouse and Potter, 2001; Jones et al., 2000; Simpkins et al., 2017).

Informal education is often overlooked in education policy discussions compared to formal education, which is unfortunate considering K-12 age students spend the majority (81%) of their time in non-school settings (National Research Council [NRC], 2009). Informal education has been cited as beneficial because it allows learners to engage with concepts in environments that provide them time and space to cognitively struggle with ideas. STEM focused afterschool and summer programs can give learners time to practice STEM skills, such as asking questions, communicating ideas, and drawing conclusions. Research has identified the key components of successful programs as: exposure to STEM role models and participation in hands-on activities that give students an opportunity to learn about STEM fields, improve their confidence in their ability to be successful in these fields, and see themselves as potential participants and contributors in these fields (Adams et al., 2014; Brickhouse & Potter, 2001; Cakir et al., 2017; Carlone & Johnson, 2007; NRC, 2009; Olitsky, 2006; Painter et al., 2006; Polman & Miller, 2010; Riedinger & Taylor, 2016). The informal STEM education program that is the basis for this study adheres to all of these best practices (Roberts & Hughes, 2019). The camp in this study aims to directly challenge pre-conceived notions of STEM and give girls a chance to meet female scientists, participate in hands-on learning, and make connections between classroom learning and real-life applications (NRC, 2009). Research has shown that this style of active learning works particularly well with minority students (Chun & Harris, 2011).

LITERATURE REVIEW

Most research on STEM identity and/or STEM identity work, tells us that self-efficacy and interest play a role in the development of STEM identity (Adams et al., 2014; Eccles, 2007; Hazari et al., 2010; Rittmayer & Beier, 2009; Usher & Pajares, 2006). But few tell us how this occurs (see Riedinger & Taylor, 2016). In particular, we do not have a good understanding of how differing levels of STEM interest, self-efficacy, and STEM identity before participating in an intervention affect youth’s identity work during and upon completion of their relevant intervention. STEM self-efficacy is just one characteristic that has been shown to affect students’ STEM identity. Research demonstrates that in order for youth to become interested in STEM careers, they need to develop a sense of competence in STEM skills necessary for success, which has been defined as self-efficacy (Eccles, 2007; Hazari et al., 2010; Rittmayer & Beier, 2009; Usher & Pajares, 2006). As their competence and confidence in these skills improves, students can begin to strengthen their identification with their chosen STEM career (Carlone & Johnson, 2007; Eccles, 2007). STEM identity has been defined as one’s sense of belonging within a chosen STEM field (Carlone & Johnson, 2007). STEM identity is affected by an individual’s sense of competence and perceived ability to succeed (Eccles, 2007) within STEM as well as their opportunities to positively perform this competence and be recognized for these performances by experts (Carlone & Johnson, 2007). Consequently, there is tension between an individual’s identity work and how it is accepted or rejected by others (Calabrese Barton et al., 2013).

We recognize that identity formation occurs across time and within various spaces including: school, home, and informal education experiences (Calabrese Barton et al., 2013). Identity is therefore affected by individual decisions, social interactions, and the interpretation of these interactions and decisions over time and space. As individuals encounter new communities of practice (social and cultural), they use lessons learned in previous experiences to create new hybrid practices that can position them within the community of practice (COP). According to Lave and Wenger (1991), COPs are activity systems wherein participants share common understandings and work that has meaning in their lives and for their communities. Within these COPs, novices enter and based on their experiences, social interactions and interpretations, can remain and move from peripheral participation to legitimate peripheral participation. Agency is involved in the process, hence the term identity work in that it is ongoing and requires agency on the part of the individual (Calabrese Barton et al., 2013).

Examples of Studies on STEM identity

Despite decades of research calling for more studies that highlight the rich and complex development of identity work across multiple spaces, there are only a small number of research studies that focus on identity work (e.g. Calabrese Barton et al., 2013; Carlone, Scott, & Lowder, 2014). These studies are incredibly valuable to our understanding of STEM identity; however, the complexity of the intersectionality of the varying spaces makes it difficult to determine how identity work is occurring within each. Therefore, there is also value to studies that focus on each of the spaces wherein identity work occurs (home, school, or informal education spaces). Our study focuses on the latter so our literature review will highlight current research in informal science education spaces that are four or more days long – similar to our own programs – to better situate the reader as to how our study fits within the broader field of identity work studies.

The following literature review highlights the results of various studies that focus on informal STEM education programs' impact on STEM[1] identity. These STEM identity studies vary in terms of the research methods used as well as the overall impact of the informal STEM education program on STEM identity immediately upon completion and/or over time. Quantitative studies have shown mixed results. For example, Bhattacharyya and colleagues (2011) studied the immediate impact of a one-week summer science camp on participating students' (majority African American/Black) STEM identity as measured through changes in attitudes toward science and interest in science on a pre and post Likert-scale survey derived from Francis and Greer's (1999) attitudes towards science survey. The authors surveyed participants in three summers worth of summer science camps (2006, 2007, 2009) resulting in 313 students of which 166 were female. The authors conducted an ANOVA to determine if attitudes changed from pre- to post-survey. They found that participating girls had a positive increase in their science attitude score, however these results were not statistically significant. Similarly, Farland-Smith (2009) studied the immediate impact of a one-week STEM summer camp on girls' STEM identity as measured through the Attitude Toward Science (ATS) Survey (Ledger, 2003) and the Enhanced Draw a Scientist Test (E-DAST) (Farland & McComas, 2006) to measure attitudes/perceptions of scientist as a metric for STEM identity. The ATS included 10 Likert scale questions that were compared using t-tests from pre- to post-test and the E-DAST was coded to classify drawings in one of three categories with "limited" being the most stereotypical, followed by conflicted. The highest score was enhanced, which was used to identify diverse drawings of scientists in different careers. The resulting drawing scores were quantified and compared from pre- to post-camp via t-tests. Her results showed an increase in positive perceptions of scientists from pre- to post-test, however, these were not statistically significant. Both of these studies indicate that informal STEM education interventions have the potential to improve STEM identity for participating youth. However, based on the metrics used – STEM interest and attitudes for Bhattacharyya et al. (2011) and scientist perceptions as measured through the E-DAST for Farland-Smith (2009) – conclusions could not be made.

Jayaratne and his colleagues (2003) were able to observe quantifiable changes in their study of the impact of a two week 8th grade summer science camp on participating girls' self-concept of science abilities, interest in science, and career goals in science. The authors created their own Likert-scale survey to include these three metrics which were combined to measure science identity. Jayaratne and his colleagues measured changes from pre- to post-camp as well as four years later in 12th grade. The authors conducted an ANOVA analysis comparing four groups: minority students who participated in the program, minority students who applied but did not get in, non-minority students who participated in the program, and non-minority students who applied but did not get in. They found that non-minority girls had higher levels of self-concept and interest in science and stronger science career aspirations than minority girls. All the participants showed a decline in science self-concept and interest in science careers from 8th to 12th grade. For those who participated in the camp, these individuals were able to build their competence and perform competencies in front of recognized experts. The students also benefited from the community within the camp. All of those interviewed commented on the feeling of belonging in science. The authors concluded that this camp's unique combination of autonomy and mentoring provided students with a positive environment in which to try on their science identities. This study adds to our current understanding of best practices in informal science education programs and their longitudinal impact, but it does not help us understand how strong participating youth's STEM identity was before participating and how this STEM identity work occurs during the intervention.

Qualitative studies have shed some light on how STEM identity work occurs during informal STEM programs. Painter and his colleagues (2006) conducted a qualitative study of 64 7th and 10th grade students' perceptions of scientists before and after a week-long nanotechnology program. The authors interviewed all 64 participating youth two weeks before and one week after the program. The authors kept field notes to record all verbal conversation between students and scientists and document nonverbal behaviors of students and conducted follow-up interviews with 15 randomly selected participants one year later. After the program, the students no longer perceived scientists as mainly men wearing white lab coats doing experiments in sterile, boring, lonely labs. The follow-up interviews indicated that these positive changes in perceptions of scientists remained even after a year. Therefore, the authors concluded that exposure to scientists helped change the students' stereotypes. This qualitative study provides a more detailed picture of how programs can improve perceptions of scientists but is limited in a full understanding of identity development because it focuses only on one aspect of identity – perception of scientists – and only 15 participants.

Riedinger and Taylor (2016) followed 12 girls across five case sites – Coastal Ecology science camp, a 4-day summer camp – between 2011 and 2013. In their qualitative study, they collected focus group data, observation data and reviewed journal prompt entries. The authors found that the aspects of Coastal Ecology that positively impacted the girls' science identity were: authentic opportunities for active learning; unique outdoor learning experiences; comfortable and personally relevant settings; multiple types of language (e.g. academic science versus everyday language); and opportunities for social interaction. The authors' lens for identity highlights that identity work is an ongoing and evolving process. However, in their study, they do not indicate how they measured participants' pre and post identity. This makes it difficult to replicate or generalize this study.

Other STEM identity studies have focused on the role that communities of practice and figured worlds can play in identity work. For example, Barab and Hay (2001) focused on a Science Apprenticeship Camp (SAC), a two-week science camp wherein 24 middle school students were paired with scientists to work on scientific research. The data collected included: observation/field notes for all parts of camp including final presentations; notebook/journals; and semi-structured interviews with students. The results indicated that students were able to gain practice in using the language of the scientific community and participate in the discourse and perceived their work as legitimate. The authors concluded that the camp was too short and the students too young to move to full authentic participation, but they were able to witness some movement toward this eventual step. Gonsalves and her colleagues (2013) used sociocultural theory to determine how science was figured and re-figured over time by participating middle school girls in an afterschool program. Figured worlds are "socially constructed realms of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others" (Holland et al., 1998 p. 52). For this study the figured worlds of science were the activities and conversations that took place over time in the club. The data collection included observations, interviews, and focus groups. The results indicated that it was difficult for these girls to move away from a limiting view of science. They believed that science was simply the type of science they learned about in school and that they perceived as irrelevant to their lives – especially for youth coming from historically marginalized backgrounds (e.g. lower income and people of color). The authors concluded that even if these young women successfully re-figured science, they still could not see their own contributions and experiences as central to real science. These studies highlight issues affecting youth from fully identifying with STEM fields. However, neither were able to determine what level of STEM identification students had before the intervention and how their varying levels of STEM identity could impact their identity work during and after the program.

Our literature review indicates that research on informal STEM education programs, particularly for girls, is important to understand STEM identity work. However, what is currently missing from this research is an understanding of where each girl enters the program in terms of her STEM identity work and how a program that utilizes best practices (role models, hands-on relevant STEM work) can impact each of those girls. Consequently, our study seeks to examine the impacts of girls' STEM self-efficacy on their growth in STEM identity after participating in a middle school girls-only STEM summer camp (STEM-Girls[2]). The research questions guiding this study are:

1. Does participation in STEM-Girls increase girls' STEM identity and self-efficacy?
2. What role does the girls' STEM self-efficacy play in their growth of STEM identity?

CONCEPTUAL FRAMEWORK

Our guiding framework was based on Calabrese Barton and her colleagues' conceptual framework (2013) focusing on identity work. As individuals encounter new communities of practice (social and cultural), they use lessons learned in previous experiences to create new hybrid practices that can position them within the community of practice (COP) (Lave & Wenger, 1991) as a central or peripheral member. It is our contention that the STEM-Girls camp could be considered students' first exposure to the COP of STEM. In addition, the social interactions within the camp and the resulting camp events can have an effect on participants' STEM identity trajectories. Therefore, hierarchical linear modeling (HLM) is a valid form of analysis since it can measure growth of participating campers' STEM identity over the time of the camp.

One of the key pieces of Calabrese Barton and her colleagues' framework is the tension that exists between an individual's identity work and how it is accepted or rejected by others. This is supported by Carlone and Johnson's (2007) science identity framework that advocates that in order for individuals to identify with STEM, they must have opportunities to develop competency in STEM fields, perform these competencies, and be recognized by perceived experts. Therefore, we divided our STEM identity metrics into those that included each participant's sense of STEM identity or sense of belonging in STEM and their perception of how others viewed them in terms of being a science person. A second key piece of Calabrese Barton and her colleagues' framework is that identity work occurs across three spaces (home, school, and out of school). Although we could not observe these three spaces, our survey questions did ask participants to indicate their level of identification with STEM and being a STEM person in each of these spaces and whether their peers and family saw them as STEM people as well.

In addition to Calabrese Barton's work, we wanted to measure other aspects of students' STEM identity that have been identified by researchers as aspects affecting girls' STEM identity development. These include: STEM interest (Eccles, 2007; Gilmartin et al., 2007; Hazari et al., 2010); and self-confidence and self-efficacy in STEM (Eccles, 2007; Hazari et al., 2010; Rittmayer & Beier, 2009; Usher & Pajares, 2006). Aschbacher and colleagues' (2010) survey tool along with the Assessing Women in Engineering (AWE) (2008) survey tool both have scales for these metrics (interest, self-confidence and self-efficacy). Consequently, we were able to measure each participants' STEM identity before they participated in the camp and then after to determine changes.

METHODS

Setting of Study: Participants in STEM-Girls

This study focused on changes in STEM identity for 145 middle school girls (ages 10-14) who participated in the STEM-Girls program during the 2013-2016 summers in the U.S. STEM-Girls is a two-week STEM focused all-girls summer camp. The camp is housed at a national laboratory that is affiliated with a large research university. Local teachers work with female scientists to plan relevant hands-on activities and field trips to expose participating girls to a variety of STEM careers and types of problem-solving activities that can be experienced within those careers. Teachers design the camp activities around the best practices for informal science education programs outlined by the National Research Council (2009). Appendix A identifies typical activities and how they align with the NRC's (2009) best practices. Local girls apply to the camp in the spring. The camp teachers select applicants with the goal of giving a diverse variety of girls an opportunity to participate. This means girls from different schools and with different experiences are selected for 30-35 spots annually. Most of the girls have an interest in STEM before the camp but low levels of experience with, or exposure to, STEM careers. Demographic information for camp participants is available in Table 1.

Table 1. Single-Sex Camp Participant Demographics

Age[3]	Percent
10	1.4%
11	23.2%
12	28.2%
13	31.0%
14	14.8%
15	1.4%
Race/Ethnicity*	
Asian	21.7%
Black or African American	20.3%
White or Caucasian	53.8%
Hispanic or Latino/a	7.0%
Other Demographics	
Currently enrolled in honors or advanced classes	81.8%

*Youth could check all that apply therefore total is more than 100%

Data Collection and Survey Instrument

The survey for this project measured STEM Self-Efficacy, STEM Identity, and demographic information. The data were collected via a pre- and post-camp survey. Both surveys included questions from the Assessing Women in Engineering Middle School Core Survey (AWE, 2008) and The *Is Science Me?* survey created by Aschbacher, Li, and Roth (2010). All quantitative questions are a five-point Likert scale, one being strongly disagree and five being strongly agree. The list of questions and the associated metrics are found in Appendix B.

The survey questions fell into two scales: *STEM Identity* and *STEM Self-Efficacy*. All students were given a pre- and post-camp survey with questions from the instruments measuring *STEM Identity* and *STEM Self-Efficacy* (see Appendix B). The capitalized version of STEM Self-Efficacy and STEM Identity are used to reference concepts as measured by our chosen metrics, whereas lower case references refer to the broader concepts across the literature. Exploratory factor analysis was conducted on the questions from the surveys to develop scales. All items with a factor loading of 0.4 or greater were considered for inclusion. Selected items received equal weighting in the scales for our first phase of analysis. After reviewing the factor loadings, we analyzed the questions that loaded together to conceptualize the subscales. To see all items included and which questions loaded into each sub-scale, please see Appendix B.

Within the *STEM Identity* scale, two subscales emerged. The first we labeled S*elf-Perception* (ɑ = .873) because these six items focused on how the respondent saw themselves in reference to science, such as science being an important part of who they are. The second subscale was *External Perception* (ɑ = .881). These six items centered on how the respondent perceived others' views of them along with questions related to them doing science among others.

For the *STEM Self-Efficacy* scale, we observed three different subscales. The first subscale here was *Self-Confidence* (ɑ = .840). These seven items focused on students' sense of competence in science including their abilities to achieve high grades, explain science concepts and use knowledge to solve problems. The second subscale was *Openness to Challenge* (ɑ = .814), which included seven items related to the desire to put themselves in challenging situations (e.g. persevering when an assignment becomes harder than expected). We considered this to be an aspect of *STEM Self-Efficacy* due to the pervasive notion that STEM fields are particularly challenging academically. Dweck (2006) found that this perception is especially true for girls who see math as an innate ability that is predominately found in boys. This finding was echoed in our exploratory factor analysis, as all four math questions loaded onto a factor with the questions asking about challenging situations. These seven items together addressed both actual and perceived challenges that students face as they pursue their STEM interests. The final subscale in the STEM Self-Efficacy scale was *Willingness to Learn* (ɑ = .791). These six items focused on respondents' interest in learning science in school and how quickly they perceive their mastery of the subject.

Our primary covariates were student demographic characteristics including race, ethnicity, age, and whether or not they were enrolled in advanced classes. STEM Identity, which was comprised of two subscales – Self Perception (ɑ = .873) and External Perception (ɑ = .881) – served as our primary outcome variable. STEM Self-Efficacy, which was comprised of three subscales – Self Confidence (ɑ = .840), Openness to Challenge (ɑ = .814), and Willingness to Learn (ɑ = .791) – was an intermediate outcome which we examined on its own and as a potentially mediating variable in our STEM Identity models.

Analysis

Our analysis was driven by two research questions:

1. Does participation in STEM-Girls increase girls' STEM Identity and STEM Self-Efficacy scores?
2. What role does the girls' STEM Self-Efficacy play in their growth of STEM Identity?

To answer these research questions, we tested the following hypotheses:

H_1: Participation in STEM-Girls will increase participants' STEM Self-Efficacy and STEM Identity

H_2: Girls with lower pre-camp STEM Self-Efficacy will have greater gains in STEM identity post-camp.

Phase one of our analysis was a linear regression to allow us to examine trends in the pre- and post-scores on our scales. These linear regression results provided a snapshot of the students' STEM Self-Efficacy and Identity scores before and after the camp. Linear regression only allows us to see the pre- and post- results at individual points in time. For phase two, we conducted hierarchical linear modeling (HLM) which would allow us to analyze individual growth over the two weeks of the camp. These combined analyses allow us to answer the two research questions.

Missing Data Procedures

Any students who did not complete the pre- or post-camp survey were removed using case-wise list deletion (i.e. any student who was not present for both the pre and post survey was removed from the dataset). This left 145 participants who had occasionally skipped individual survey questions. For these students, missing responses were imputed using Multiple Imputation in SPSS 23. We conducted 10 iterations of multiple imputations and used pooled results of analyses. There was no missing demographic information in the dataset, only individual questions.

RESULTS

To test our first hypothesis, we needed to determine each participant's level of STEM Self-Efficacy and STEM Identity before participating in the camp in order to determine each individual's improvement in these two scales. In terms of race and ethnicity, students entered the camps with similar levels of pre-camp STEM Self-Efficacy (Table 2) and STEM-Identity (Table 3). We observed statistically significant differences in STEM Self-Efficacy and STEM Identity based on other demographics. Older students identified lower levels of STEM self-efficacy than their younger peers. For each year of age, the participants lost an average of .114 on the self-efficacy scale. Older students exhibited lower scores than their younger peers in the following: Willingness to Learn (β= -.088, p= .029), Openness to Challenge (β= -.189, p= .046), and STEM Self-Efficacy overall (β= -.234, p=.045). In addition, we found that students who enrolled in honors or advanced classes had lower scores on their pre-camp Openness to Challenge scale (β= -.378, p=.004).

Table 2. Student Characteristics as Predictors of Pre-Camp STEM Self-Efficacy

Student Characteristics	Beta (Standard Error)
Black or African American	-0.015 (0.177)
Hispanic or Latino/a	0.074 (0.180)
White or Caucasian	-0.110 (0.163)
Asian	0.075 (0.171)
Age	-0.114*** (0.036)
Enrolled in Honors or Advanced Classes	-0.234** (0.101)
Observations	145
R-squared	0.127
*** p<0.01, ** p<0.05, * p<0.1	

Table 3. Student Characteristics as Predictors of Pre-Camp STEM Identity

Student Characteristics	Beta (Standard Error)
Black or African American	-0.147 (0.279)
Hispanic or Latino/a	0.022 (0.292)
White or Caucasian	-0.136 (0.292)
Asian	-0.035 (0.271)
Age	0.010 (0.060)
Enrolled in Honors or Advanced Classes	0.067 (0.163)
Openness to Challenge	0.320*** (0.105)
Observations	145
R-squared	0.124
*** p<0.01, ** p<0.05, * p<0.1	

These differences (age and enrollment in honors/advanced classes) persisted even after participation in STEM-Girls (Tables 4 and 5). Age remained a negative predictor for Openness to Challenge (β= -.189, *p*=.000) and STEM Self-Efficacy overall (β= -.135, *p*=.001, Table 4). Being enrolled in honors or advanced classes also continued to be a negative predictor of STEM Self-Efficacy (β= -.135, *p*=.034). Race and ethnicity were not a significant predictor of post-camp STEM Self-Efficacy (Table 4) or Identity (Table 5).

Table 4. Student Characteristics as Predictors of Post-Camp STEM Self-Efficacy

Student Characteristics	Beta (Standard error)
Black or African American	-0.035 (0.169)
Hispanic or Latino/a	0.011 (0.172)
White or Caucasian	-0.127 (0.156)
Asian	0.014 (0.164)
Age	-0.135*** (0.034)
Enrolled in Honors or Advanced Classes	-0.279** (0.097)
Observations	145
R-squared	0.149
*** p<0.01, ** p<0.05, * p<0.1	

Table 5. Student Characteristics as Predictors of Post-Camp STEM Identity

Student Characteristics	Beta (Standard error)
Black or African American	-0.138 (0.286)
Hispanic or Latino/a	-0.101 (0.297)
White or Caucasian	-0.140 (0.265)
Asian	-0.041 (0.278)
Age	0.009 (0.060)
Enrolled in Honors or Advanced Classes	-0.051 (0.168)
Openness to Challenge	0.214** (0.107)
Observations	145
R-squared	0.064
*** p<0.01, ** p<0.05, * p<0.1	

While phase one analyses focused on “snapshots” of specific time points (i.e. pre- or post-scores), phase two analyses modeled change over time in order to better understand how participants’ STEM Identity and STEM Self-Efficacy changed from pre- to post-camp. We utilized findings from phase one to guide the analyses in phase two. For the phase two analyses (Tables 6-8), we used hierarchical linear modeling (HLM) to examine growth in STEM Self-Efficacy and STEM identity, and the impacts of the Openness to Challenge component of STEM Self-Efficacy on STEM Identity. Scales and subscales at both time points served as our level one variables and student characteristics (age, race, and being enrolled in honors classes) served as our level two characteristics to model nested time points within individuals, as outlined by Shek and Ma (2011). This allowed us to examine changes in students’ STEM Self-Efficacy and STEM Identity while still controlling for demographic characteristics rather than viewing their pre- and post-camp scales as separate time points.

For STEM Self-Efficacy (Table 6), overall we did not see a significant change from pre- to post-camp based on race, ethnicity, or age. Because Openness to Challenge was such a significant predictor in the phase one analyses, in phase two we decided to examine the role of Openness to Challenge specifically in both STEM Self-Efficacy and STEM Identity growth. Pre-camp Openness to Challenge was found to be a significant positive predictor of post-camp STEM Self-Efficacy (β=0.535, *p*=.000), and as students' Openness to Challenge increased over time, their STEM Self-Efficacy grew at a slightly increased rate (β=0.061, *p*=.061). These findings support our phase one results that suggest that a student's Openness to Challenge is more impactful than any demographic characteristics and is a key component of a student's STEM Self-Efficacy in shaping their STEM Identity. Race and ethnicity were not found to be significant predictors of either post-camp Openness to Challenge or growth in Openness to Challenge. Age, however, was a negative predictor of post-camp Openness to Challenge, indicating that older students were less likely to be open to challenge.

Table 6. HLM Results for STEM Self-Efficacy

Factor	Beta (Standard error)
Time (Pre to Post change)	-0.107 (0.349)
Black or African American	-0.047 (0.149)
Hispanic or Latino/a	0.044 (0.150)
White or Caucasian	-0.021 (0.137)
Asian	-0.042 (0.143)
Age	0.006 (0.031)
Openness to Challenge	0.535*** (0.054)
Time*Black or African American	-0.004 (0.080)
Time*Hispanic or Latino/a	-0.105 (0.080)
Time*White or Caucasian	-0.015 (0.072)
Time*Asian	-0.040 (0.076)
Time*Age	-0.010 (0.028)
Time*Challenge	0.061* (0.033)
Observations	145
ICC	0.679
*** p<0.01, ** p<0.05, * p<0.1	

Our phase two analysis for STEM Identity (Table 7) showed similar results as STEM Self-Efficacy. Pre-camp Openness to Challenge was a significant predictor of post-camp STEM Identity, regardless of student demographic characteristics (β=.338, *p*=.006). However, unlike STEM Self-Efficacy overall, Openness to Challenge alone did not significantly impact students' growth in STEM Identity. Race and ethnicity were not found to be significant predictors of either post-camp Openness to Challenge or growth in Openness to Challenge. Age, however, was a negative predictor of post-camp Openness to Challenge, indicating that older students were less likely to be open to challenge.

Table 7. HLM Results for STEM Identity

Factor	Beta (Standard error)
Time (Pre to Post change)	-0.475 (0.650)
Black or African American	-0.189 (0.367)
Hispanic or Latino/a	0.133 (0.391)
White or Caucasian	-0.166 (0.336)
Asian	-0.077 (0.352)
Age	-0.012 (0.078)
Openness to Challenge	0.338*** (0.124)
Time*Black or African American	0.022 (0.180)
Time*Hispanic or Latino/a	-0.157 (0.197)
Time*White or Caucasian	0.020 (0.167)
Time*Asian	-0.004 (0.173)
Time*Age	0.030 (0.038)
Time*Challenge	0.040 (0.073)
Observations	145
ICC	0.785
*** p<0.01, ** p<0.05, * p<0.1	

Table 8. HLM Results for Openness to Challenge

Factor	Beta (Standard error)
Time (Pre to Post change)	-0.002 (0.335)
Black or African American	0.156 (0.280)
Hispanic or Latino/a	0.312 (0.280)
White or Caucasian	-0.066 (0.257)
Asian	0.441 (0.266)
Age	-0.169*** (0.056)
Time*Black or African American	-0.025 (0.127)
Time*Hispanic or Latino/a	0.053 (0.127)
Time*White or Caucasian	0.013 (0.116)
Time*Asian	-0.047 (0.121)
Time*Age	-0.002 (0.025)
Observations	145
ICC	0.827
*** p<0.01, ** p<0.05, * p<0.1	

DISCUSSION

Our first research question asked what role participation in the summer camp had in shaping girls' STEM Self-Efficacy and STEM Identity. Our linear regression analyses indicated that girls with a higher pre-camp Openness to Challenge score (a subcomponent of STEM Self-Efficacy) had a higher STEM Identity both pre-camp and post-camp. Our HLM analyses indicated that there was no consistent growth in either STEM Self-Efficacy or STEM Identity from pre- to post-camp leading us to conclude that participation in the camp did not significantly improve STEM Identity or STEM Self-Efficacy.

This is not necessarily a failure of the intervention as we saw when we began to answer our second research question. This question asked what role STEM Self-Efficacy, particularly Openness to Challenge, specifically had on STEM Identity. Phase one analyses included linear regression analysis to examine which subscales and demographics had the most impact on participants' STEM Self-Efficacy and STEM Identity. This analysis indicated that race and ethnicity were not significant predictors for either the pre-camp or the post-camp STEM Self-Efficacy and STEM Identity scores. Age and enrollment in honors and/or advanced courses were significant negative predictors of both STEM Identity and Self-Efficacy. However, when the Openness to Challenge component of Self-Efficacy is added to the STEM Identity model, statistical significance for both characteristics drops, with only the Openness to Challenge subscale remaining significant. This highlights that a girl's Openness to Challenge is a better predictor of STEM Identity than any demographic characteristic. This fits with our original hypothesis that STEM Self-Efficacy, particularly the Openness to Challenge subscale, is positively correlated to pre- and post-camp STEM Identity. This result indicates that more research is needed to further investigate the importance of developing students' growth in their Openness to Challenge in informal STEM education since it appears to be the driving component of STEM Self-Efficacy that has a significant role in STEM identity development. Dweck (2006) points to the concept of the growth mindset, wherein mistakes are part of the learning process and not failures. Few informal science education research studies have looked at the impact of instilling an openness to challenge in their participating youth's mindset. Educators can create a learning environment and present activities in a way that youth are encouraged to try new things. Informal science education spaces are structured in a way that youth are given space and time to make mistakes and work through authentic science opportunities.

Research has indicated the importance of intersectionality in the study of girls' and women's STEM identity (Tan & Calabrese Barton, 2008; Tan et al., 2013). Our study indicates that race and ethnicity did not affect our participants' STEM Self-Efficacy and STEM Identity. Rather, age and enrollment in advanced classes were the significant predictors of pre-camp levels of STEM Self-Efficacy. The older students in the STEM-Girls camp had lower STEM Self-Efficacy and STEM Identity. Research demonstrates as girls move through formal schooling, they begin to struggle with the good student stereotype (Carlone, 2003; Tan & Calabrese Barton, 2008). Teachers and parents support the idea that for girls to be considered good students, they must be obedient, conforming, and know answers to questions. As girls move through secondary school, they often see low grades or giving incorrect answers as examples of failure (Williams & Ceci, 2007). Again, Dweck's work (2006) on the growth mindset challenges this stereotype of innate ability but girls do not often learn how to develop a growth mindset. Our study indicates that as girls enter middle school, particularly at the higher grades, their self-efficacy in STEM declines and they identify less with STEM. In particular, our participants who were enrolled in advanced courses (high achievers) struggled with lower STEM Self-Efficacy and STEM Identity. Our study does not allow us to identify why this is, but the results support previous research highlighting how girls begin to lose interest in STEM as they move through secondary school. When girls encounter challenges as they move through higher level courses, they associate these challenges with failure rather than seeing them as opportunities to improve skills (Williams & Ceci, 2007). STEM-Girls was designed to strengthen participating girls' STEM Identity. However, it would appear that the program should focus more on strengthening girls' Openness to Challenge (e.g. making problem solving and learning from mistakes fun) in order to improve their STEM identity.

LIMITATIONS AND IMPLICATIONS FOR FUTURE RESEARCH

We acknowledge that this study focuses on one program. Future studies should compare these same metrics across multiple programs to determine the influence of varying interventions on STEM Self-Efficacy and STEM Identity. The results of this study indicate that informal STEM education programs might need to implement more opportunities for girls to grow in their openness to challenge. Educators can create a learning environment where learning by making mistakes is considered the norm but where this type of activity can also be fun. Program practitioners might want to develop interventions around this concept to strengthen programs so that they can improve girls' openness to challenges as a normal part of STEM. In addition, our research indicates that high achievers struggle with their sense of openness to challenge. Future research should focus on whether this is common across programs. Practitioners could utilize Dweck's (2006) work in their interventions to address high achievers' lowered sense of openness to challenge.

Additionally, this camp is only two weeks long. As a result, the growth trajectories in this study only capture girls' growth in STEM Self-Efficacy and STEM Identity over a two-week period. Both STEM Self-Efficacy and STEM Identity are complex concepts that are built and shaped over a life time. As such, it is not necessarily surprising that we did not see significant growth trends across participants. In order to gain a greater understanding of how STEM Self-Efficacy and STEM Identity change over time, future research should expand their focus of study to include data collection at more time points over a longer period of time than we were able to capture in this study.

As is the case with any study that does not include random assignment to a treatment, our sample is also subject to selection bias. Consequently, the campers could have entered with a relatively high STEM Self-Efficacy and STEM Identity, compared to the general population. Future studies should include survey results from participants from the general population to compare pre-scores.

CONCLUSION

One of our goals for this study was to determine if our current model could help us understand changes in STEM Identity and STEM Self-efficacy during a two-week camp. Our results indicated that participation in the camp did not have a significant impact on changes in STEM Identity and STEM Self-Efficacy. As we stated above, this could simply be because the intervention was too short or more time is needed to see the impact of an intervention on these scales. We had hoped to provide a quantitative measurement to Calabrese Barton and colleagues' framework (2013) but could not measure significant change.

Despite these limitations, we were still able to introduce the importance of the Openness to Challenge component of STEM Self-Efficacy as a predictor of STEM Identity. Our initial goal for this study was to identify what impact STEM-Girls had on participating youth. We found that Openness to Challenge was the highest predictor of STEM identity, meaning that girls who were more open to challenge had a stronger STEM identity than those who were fearful of challenge – failure. Our study indicates that informal science education programs should provide opportunities for girls to improve their Openness to Challenge as this was the strongest predictor of STEM identity. Middle School currently represents a crucial point in the STEM pipeline where many students, and especially girls, are being lost. Two reasons scholars have provided for this trend are diminished self-confidence (Dweck 2006; Eccles, 2007) and an inability to perceive themselves as scientists (Carlone & Johnson, 2007; Ceci et al. 2009). Helping these students to improve their reaction to challenge and build confidence may be the key to equalizing access to, and success in, STEM fields, thereby improving girls and women's representation in STEM fields.

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ENDNOTES

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[1] Please note that the authors use the acronym STEM because our intervention focuses on all four aspects, but we have chosen to use the terms (e.g. science) that the researchers used for each of their studies rather than STEM throughout.

[2] Pseudonym for the actual camp name.

[3] School grade is not included because respondents were often confused by this question. (Since STEM-Girls is a summer programs, girls would be confused as to whether to put the grade they just completed or the one they would be entering in the fall.

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Appendix A: Example of Camp Activities and Relevance to NRC Framework

	Activity	How Activity Fit within Goals of Camp
Day 1 (AM)	Tour of national laboratory facility where camp is housed. Tour guides included teachers and another educator familiar with laboratory (female and male teachers).	*Exposure to STEM*: Showed participants multiple opportunities in STEM and the value each of these plays in research at the laboratory. *Exposure to STEM Professionals*: Showed types of opportunities at the lab within the larger community of science.
Day 1 (PM)	Water testing. The participants learn about the effects of pollutants on local waterways and the role of observation in research. They then test the pond behind laboratory and record data and discuss why these results could be this way (female teachers).	*Exposure to STEM*: Participated in the process of science (collection and analysis of data) *Relevance of STEM:* Made the focus of the camp relevant to their daily lives.
Day 2 (AM)	Two representatives from the state Environmental Protection Agency and one representative from a local engineering firm, specializing in water testing led the girls on a hike on local trails. They discussed the ecosystem, the role of water, the type of waterways. The girls then tested the water at two locations. Discussed the ecosystem and its role in their data (1 male scientist, one female scientist, 1 female science graduate participants, 4 female teachers).	*Exposure to STEM*: Participated in the process of science (data collection and analysis). *Relevance of STEM:* Saw the interconnectedness of water systems and why water quality is important for healthy ecosystems. *Exposure to STEM Professionals*: Saw scientists at work and learned about possible careers in STEM.

Day 2 (PM)	Tour of local waterway and ecosystem by marine biologist (female scientist)	*Relevance of STEM:* Made the focus of the camp relevant to their daily lives. *Exposure to STEM Professionals*: Saw scientists at work and learned about possible careers in STEM.
Day 3	Toured local animal shelter. The veterinarian took participants on tour, had them watch and assist in a spay surgery, during which she explained the importance of such processes, learned about various diseases that affect animals within pets and larger local ecosystems, and observed parasites under a microscope. At the end the veterinarian explained her life history as it relates to science and answered participants' questions (female veterinarian and female veterinarian technician staff).	*Relevance of STEM:* Made the focus of the camp relevant to their daily lives. *Exposure to STEM Professionals*: Saw scientists at work and learned about possible careers in STEM.
Day 4	Toured local organic farm to learn about the role of pesticides on produce and how organic farms attempt to fit in with the local ecosystem. Discussed sustainability in organic farming and the science behind organic farming (i.e. soil and water testing, native species versus invasive species). (Male and female farmer.)	*Relevance of STEM*: Made the focus of the camp relevant to their daily lives. *Exposure to STEM*: Showed them science opportunities and applications beyond careers.
Day 5	Visited local marine laboratory facility. The participants learned differences between inference and observation, the role of the moon on the tides, and observed various species under the microscope. Then they snorkeled in a local marine waterway, observed various ecosystems (sea grass, oyster beds). The older girls conducted a survey of mole crabs, measuring where they lived along the coast and counting the number of each sex and age. Then spoke with a female marine biologist and did a hands-on activity	*Relevance of STEM*: Made the focus of the camp relevant to their daily lives. *Exposure to STEM*: Observed ways in which STEM careers can be used in educative ways—not only within a research laboratory. *Exposure to STEM Professionals*: Saw scientists at work and learned about possible careers in STEM.

	related to her research, testing the best conditions for periwinkle snails to live. (Female facilitator with background in marine biology).	
Day 6	Visited a local wolf preserve and learned about the role that science understanding can play in policy changes, like wolves' presence on the endangered species list (owned by a female non-scientist).	*Relevance of STEM:* Made the focus of the camp relevant to their daily lives. *Exposure to STEM*: Showed them science opportunities and applications in policy.
Day 7	The girls worked in groups to analyze and create a presentation on the water testing data that they had collected throughout the camp. Participants were encouraged to make inferences based on their observations and data regarding the health of the local waterways (female teachers).	*Relevance of STEM:* Made the focus of the camp relevant to their daily lives. *Exposure to STEM*: Participated in the process of science (collection and analysis of data)
Day 8	Older girls listened to a presentation and various demonstrations by a female engineer who discussed her work with nanotechnology. After the presentation, the girls constructed nanotubes out of balloons and hula-hoops. In her discussion, the female engineer, related nanotechnology to items used by the girls (female engineer). The younger girls learned about water filtration and the design of man-made structures that would help purify water in local parks. Then the girls constructed their own filtration systems (three female engineers).	*Relevance of STEM*: Made the focus of the camp relevant to their daily lives. *Exposure to STEM*: Learned about many different facets of engineering and the different types of engineering opportunities available. *Exposure to STEM Professionals*: Saw scientists at work and learned about possible careers in STEM.
Day 9	The girls visited a local quarry where they were able to explore and collect specimens of bone, teeth, fossils, and rocks. At the end of the day, they showed each other what they had found and the three scientists/engineers explained what it was and how they determined how old these specimens were (female	*Exposure to STEM*: The girls learn about the process of science (inferences and observations), challenging the conception of scientific theories as never changing objective truths. *Exposure to STEM Professionals*: Saw scientists at work and learned about possible careers in STEM.

	geologist, male engineer, male paleontologist).	
Day 10	Girls finalized their presentations.	*Relevance of STEM*: Made the focus of the camp relevant to their daily lives.

Appendix B: Questions from each subscale

Scale	Subscale	Items
STEM Identity	Self-Perception	• Science is something I rarely even think about. (Reverse Coded) • I would feel a loss if I were forced to give up doing science. • I really don’t have any clear feelings about science. (Reverse Coded) • Science is an important part of who I am. • Being a scientist is an important part of my identity. • No one would really be surprised if I just stopped doing science. (Reverse Coded)
	External Perception	• I am likely to choose a career in science. • I spend much of my time doing science related activities. • Many people think of me in terms of being a scientist. • Other people think doing science is important to me. • It is important to my friends and relatives that I continue as a scientist. • Many of the people that I know expect me to continue as a scientist.
STEM Self-Efficacy	Self Confidence	• I can understand difficult ideas in school. • I can explain science to my friends to help them understand. • I can get good grades in science. • I can effectively lead a team to design and build a hands-on project. • In lab activities, I can use what I have learned to design a solution. • I can teach myself to use new technologies. • I can use what I know to design and build something mechanical that works.
	Openness to Challenge	• I look forward to math class in school. • I am capable of getting straight A’s.

		• I like classes that are easy for me more than classes that challenge me. (Reverse Coded) • When an assignment turns out to be harder than I expected, I usually don't complete it. (Reverse Coded) • I can get good grades in math. • I can explain math to my friends to help them understand. • When I see a new math problem, I can use what I have learned to solve the problem.
	Willingness to Learn	• I look forward to science classes in school. • I like learning how things work. • I can learn new ideas quickly in school. • I am good at learning new things in school. • School is easy for me. • I can get good grades in science.