SciGirls Final Report 2018

A Twin Cities Public Television Project

Funded by the National Science Foundation

Experiential Science Education Research Collaborative

Inspiring girls in STEM.

Center for STEM Learning
UNIVERSITY OF COLORADO **BOULDER**

STEM Program Impacts...

"I enjoy STEM subjects. I just think they're a great way to reach out to new things and I think all STEM subjects can be found and applied in your everyday life. It's most often in subtle ways but it's really easy to find reasons how, like I did with my video about the science behind baking."

- SciGirls Student Journal

Executive Summary

SciGirls Strategies:

This report presents findings of the SciGirls Strategies quasi-experimental mixed methods study, investigating the experiences and outcomes of female high school students in classes taught by SciGirls-trained educators in terms of STEM-related identity construction. The STEM-related identity framework and research model used to guide this investigation is presented along with the study's research questions: 1) How does the experience of participating in all of the SciGirls Strategies project components impact girls' STEM-related identity development?; 2) What are the impacts of individual project components, with a focus on the use of role models in classroom instruction?; and 3) What modifications to the STEM identity framework are indicated by the findings?

Findings indicate female student experiences in classes led by ScigGirls-trained educators showed significant results towards the development of more positive STEM-related identities. The results of both quantitative and qualitative compo-

nents of this mixed methods study support the growth of STEM-related identity in seven of nine key composite indicators, including: Personal Relevance, Agency, Emotional Connection, Content Confidence, Enjoyment of Science, Science Career Interest, Technology Career Interest, Engineering Career Interest, Mathematics Career Interest. Case studies provided important insights of how lived experiences including those dimensions unfold in the personal lives of girls, including the importance of STEM-learning-related risk experiences and social factors as important components in forging agency and emotional connections to STEM.

The engagement of role models was revealed to be a significant and complex factor in the development of positive STEM-related identity. The use of female STEM by educators showed statistically significant advantages over no use. In-person role model interactions showed advantage over video based and/or article-reading exposure to role models. However, the case studies revealed

the concept of "role models" to be somewhat alien to girls, in favor of a broader concept of "personal influencers" in their lives. These were most often relatives or friends who had a high degree of personal relevancy for girls. These findings are discussed in terms of the need to recognize and articulate different kinds of role models in service to broadening participation in STEM for non-majority group students. Viewed through a social identity theory lens, it is argued necessary to unpack the monolithic concept of 'role model' to differentiate role, social, and personal influencers who exhibit traits and behaviors that inform these different levels of identity.

Finally, indicated adjustments to the conceptual framework and research model are discussed along with recommendations for future research. trategies quasi-experimental mixed methods study, investigating the experiences and outcomes of female high school students in classes taught by SciGirls-trained educators in terms of STEM-related identity construction.

Program Introduction

SciGirls Strategies was a National Science Foundation–funded project led by Twin Cities PBS (TPT) in partnership with St. Catherine University, the National Girls Collaborative, and XSci (The Experiential Science Education Research Collaborative) at the University of Colorado Boulder's Center for STEM Learning. This report presents the methods and findings of a quasi-experimental mixed-methods study designed to contribute to improved programming and knowledge in STEM-related identity development. The study tests the hypothesis that girls will develop more positive STEM-related identities when their educators employ research-based, gender-equitable and culturally responsive teaching practices enhanced with female STEM role models. The effort focuses on

the outcomes for girls engaging with the project's strategies and deliverables, including in-class experiences with SciGirls-trained teachers, and explores how those experiences contribute to their STEM-related identity development.

The larger context in which this study is positioned to contribute is the challenge of girls' entry into scientific and technical fields, which includes the challenge of developing a positive science identity against gender stereotypes (Notter, 2010; Brickhouse, Lowery, & Schultz, 2000) and maintaining that identity within a prevalent anti-science attitude among America's youth (Osborne, Simon & Collins, 2003). This challenge is amplified for girls as research indicates that sustained engagement of girls with STEM activities and career opportunities requires elements not traditionally included in STEM education: holistic human experiences that include emotions and social components, such as role modeling, integrated in the learning of content and process knowledge (Notter, 2010). If SciGirls Strategies can demonstrate successes (or failures) in integrating STEM into the processes of identity development for girls, it will generate knowledge important to the field for promoting positive STEM-related identities as an important precursor to STEM literacy and STEM career choices. It is hoped this study will also be important for educators attempting to reach learners who do not traditionally self-select for STEM learning; consider themselves culturally positioned for STEM; think themselves "smart" or "capable" enough to engage in STEM; or who actively seek to avoid the social stigma costs of participating in STEM beyond K12.

Role Models

The project placed particular emphasis on integrating role model strategies into the educator professional development for more gender equitable teaching. Role modeling has been shown to be an important factor in generating awareness

and expectations regarding role-based identity development within society (Stryker & Statham, 1985) and in promoting interest and self-efficacy among students, including minorities, in STEM fields (Aschbacher, Li & Roth, 2010; Buck et al., 2007; Ntiri, 2001; Greenwald & Davis, 2000). Multiple studies demonstrate that connecting students to STEM professionals can increase knowledge of, awareness and interest in STEM careers. Specifically, several studies show that role models can increase positive attitudes towards STEM subjects, improve self-concept in STEM, and increase greater self-efficacy in STEM (Fuesting, 2017; Clark, 2016; Herrmann, 2016; Shin, 2016). These psychosocial factors are thought to be key in promoting investment, engagement, and persistence in STEM.

However, programs directed at addressing gendered STEM interest and self-concept disparities have historically aimed to cultivate girls' STEM competences, skills and confidence within the classroom (Häussler & Hoffman, 2002). Less often, have they sought to provide positive female role models and other forms of support through internships, mentoring, and other research experiences (Hunter, Laursen & Seymour, 2006). One of the aims of this investigation was to better understand positive STEM identity role modelling for girls a sound theoretical research base so it may translate into better educational strategies for girls and boys alike at those critical teenage years where deterministic attitudes and decisions about STEM careers occur in concert with intense identity construction. In particular, this project sought to examine differences in how role models may be introduced, especially comparing video-based role models with in-person role models and/or no role models.

Research Model

The conceptual framework for this research is Social Identity Theory as described by Tajfel and Turner (1979) and later synthesized into Identity Theory by Burke and Stets (2000), which encompasses different types of program influences on identity development. Specifically, these include:

(1) Role identity: the meanings an individual assigns to different positions/functions they hold or perform in society;

(2) Social identity: the meanings an individual incorporates into their sense-of-self based on affiliation with or formal/informal membership in social groups (gender, age, family, class, ethnicity, interests), and;

(3) Personal identity: the meanings an individual incorporates into their sense-of-self as unique or distinct from others (what makes us different).

Together, these categories influence our ideas of who we are and who we want to (and attempt to) become, guiding our self-perceptions and our choices, including what we believe we can do (and what we cannot do) (Burke & Stets, 2009). In this investigation, the research team was especially interested in any positive STEM-related identity development, or the degree to which one integrates STEM into their sense-of-self as a result of their participation (McLain, 2012).

To guide the investigation, XSci began with a theoretical framework that identifies distinct STEM identity construction zones. Construction zones include the cognitive factors of agency, content confidence, emotional connection and personal relevance, and associates these factors with specific behavioral outcomes important in STEM-related identity development (capacity, STEM concept, attitudes and self-efficacy, future choices) (see Figure 1).

STEM Related Identity Construction Zones (Figure 1)
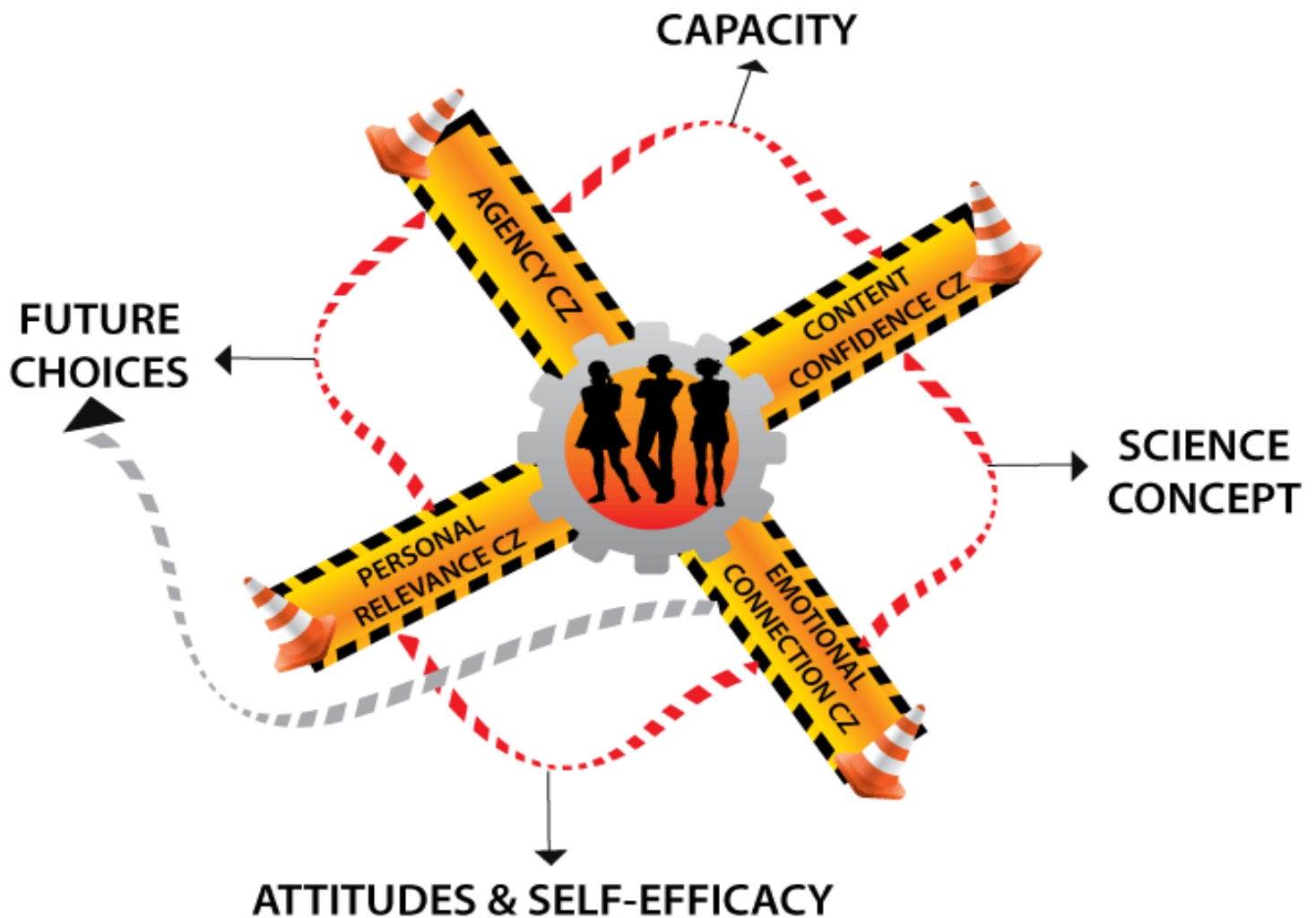

The STEM Related Identity Construction Zones

To guide the investigation of program influences (role, social and personal idenity), XSci began with a theoretical framework that identifies distinct STEM identity construction zones. Construction zones include the cognitive factors of agency, content confidence, emotional connection and personal relevance, and associates these factors with specific behavioral outcomes important in STEM-related identity development (capacity, STEM concept, attitudes and self-efficacy, future choices) (see Figure 1).
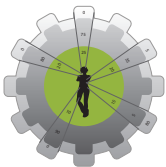
Research Questions

Question 1

How does the experience of participating in all of the SciGirls Strategies project components impact girls' STEM-related identity development?
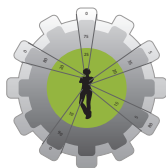
Question 2

What are the impacts of individual and project components: classroom instruction, role models, and videos and autobiographical story sharing?, with a focus on the use of role models in classroom instruction?

Question 3

What modifications to the STEM identity framework are indicated by the findings?

Case Study Highlights

Research Questions

How does the experience of participating in all of the SciGirls Strategies project components impact girls' STEM-related identity development?

What are the impacts of individual and project components: classroom instruction, role models, and videos and autobiographical story sharing?, with a focus on the use of role models in classroom instruction?

What modifications to the STEM identity framework are indicated by the findings?

In four out of the six cases, there was strong evidence of positive impacts on STEM-related identity development (see full case analysis). In two of those cases, these gains were strongly linked to in-class SciGirls-related experiences.

But in the other two cases, the positive results were not strongly linked to in-class SciGirls-related experiences, if at all. In the case one participant, there is some evidence that her STEM-related identity gains occurred in spite of some negative SciGirls-related experiences. And for two of the six cases, there were no notably positive STEM-related identity impacts linked to in-class SciGirls experiences. For one student, whose entire STEM-related identity was based in math, there was relatively little growth in broader STEM-related identity development with no major changes indicated. In the case of the one participant whose participation in SciGirls-related experiences were destructive to

"What is the science behind having a crush on someone? What sort of chemical reaction does your body go through when your mind decides it likes another person?".

- SciGirl Journal

her STEM-related identity development, her overall STEM-related identity still managed to survive as positive by the end of the semester.

Based on this framework and the findings, it is necessary to unpack the monolithic concept of 'role model' to differentiate role, social, and personal influencers who exhibit traits and behaviors that inform these levels of identity.

(For full cross case analysis please see full report)

"Learning has always been a highlight of my life, but school always hasn't... I've recently come to the realization that my life is full of challenging moments. And everyone is tested on their perseverance at some point or another. And I think as long as I can stick with what I love, I'll do just fine."

- SciGirls Participant Video Narration
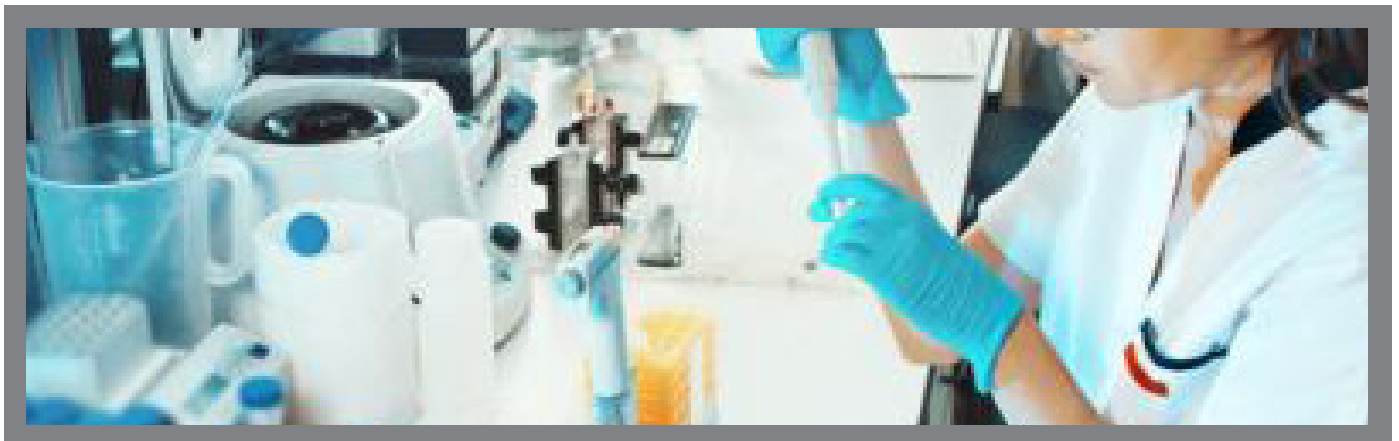
FINAL RESEARCH REPORT
2018

Bradley McLain, PH.D.
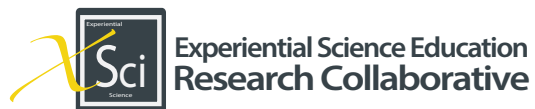

**Experiential Science Education
Research Collaborative**

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Quantitative Research

Survey Methods

To measure the impact of the SciGirls project on students, responses from a composite survey administered before and after exposure to the intervention (treatment) were compared to before and after responses from similar students who were not exposed (comparison). The composite survey consisted of the combination of the STEM Career Interest Survey, including all four subscales (Kier, Blanchard, Osborne, & Albert, 2014); The Girls' Interest in Nature and Science Scale (modified) (Flagg, 2015), and the Science Identity Scale, currently under validation testing (McLain, 2015).

The combined survey resulted in 69 common items, which align to several key concepts. For each key concept a composite score was generated[1]. See Appendix A for a list of the corresponding item for each concept. Each composite score was calculated by summing the responses to the items associated with that composite (reverse scoring when appropriate for negatively worded items) and then dividing by the total number of items. The following composites were created:

- Personal Relevance
- Agency
- Emotional Connection
- Content Confidence

- Enjoyment of Science
- Science Career Interest
- Technology Career Interest
- Engineering Career Interest
- Mathematics Career Interest

Respondents

Respondents were urban and suburban high school students identifying as female in and around the Twin Cities metropolitan area in Minnesota, USA, constituting a convenience sample of students whose teachers were in the SciGirls professional development program (treatment) and a comparison group whose teacher were not involved in SciGirls professional development. There were 547 students who completed the before-intervention (pre) survey and 315 who completed the after-intervention (post) survey. Of those, the before- and after-intervention survey data were able to be linked for 295 participants. The 295 person sample included 232 students of 17 different educators in the intervention (treatment) condition and 63 students of 3 educators in the comparison group. Surveys were collected during year 3 of the project.

The survey also asked several questions about students' background. The majority of respondents were White (62 percent), although the student racial background looked somewhat different across the experimental conditions. While 58 percent of students in the

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[1] Cronbach alpha coefficients were computed to examine the reliability of each composite. The Cronbach alpha coefficients indicated good reliability (above 0.80) for the composites related to career interest and enjoyment of science. Agency and Emotional Connection composites were slightly lower, but still considered acceptable (above 0.70).

Personal Relevance and Content Confidence were lower still (.65-.69). The decision was made to analyze these composites, but to treat results more tenuously since there is less confidence in the assumption that these items accurately measure a singular construct.

comparison group were White, only 33 percent of students in the treatment condition were White. Students were spread across grades nine through twelve, with the greatest concentration in freshman and sophomore grade (72 percent). There were larger concentrations of upper level high school students in the treatment condition (34 percent) as compared to the comparison condition (8 percent).

Analysis

First, baseline equivalence was examined between the treatment and comparison groups on each of the outcomes using an independent samples t-test. There were statistically significant differences at baseline within the STEM-CIS for engineering, technology, and mathematics career interest (independent samples t-test; $p < 0.05$). However, in all three cases, the average scores were higher for the comparison group. These results support baseline equivalence for most outcomes, and for those where inequivalence was found, the advantage is in the direction of the comparison group. To assess the impact of the SciGirls intervention on students, a series of multiple regression analyses were conducted. The analysis looked at the effect of the intervention on each of the 9 key composites. Because this study involves multiple comparisons of related outcomes, the False Discovery Rate (FDR) method[2] was used to maintain an overall Type I error rate of 5 percent.

In this kind of analysis, differences on each outcome between intervention and comparison groups is examined, controlling for student outcome score before the intervention, whether the student was in the upper grades (11th or 12th grade) and whether the student was of color. To see if the observed differences in composite scores were statistically significant (and thus, highly unlikely to be due to random chance) nine multiple regression analyses were conducted; one for each composite.

Results & Discussion

There were seven significant differences found between before-intervention and after-intervention composite scores. Students reported higher rates of the following after exposure to the intervention as compared to counterparts and after controlling for baseline differences, race, and grade level (multiple regression; $p < 0.05$):

- Personal relevance;
- Agency;
- Emotional connection;
- Content confidence;
- Enjoyment of science;
- Interest in science & mathematics careers
-

There were no statistically significant differences in interest in technology or engineering careers. Table 1 provides descriptive information on composite scores at both time points for each experimental condition. Effect sizes[3] are noted for statistically significant results. Note that for each significant finding, the effect size is small, ranging from 0.23 to

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[2] The false discovery rate method adjusts the alpha level required for statistical significance. Benjamini, Y. & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society*, B, 57, 289–300.

[3] Effect sizes of about 0.20 are typically considered small, 0.50 medium, and 0.80 large. Cohen, J. (1988). Statistical power analysis for the behavioral sciences. Hillsdale, NJ: Lawrence Erlbaum Associates

0.39. This indicates that while the program did indeed affect STEM-related identity for female students, the magnitude of that effect was relatively small.

Table 1. Composite Scores (on a <u>scale </u>of 1 to 4), by Time and Condition (Comparison vs. Treatment)

Composite	Group	Time	Mean	Std. Deviation	Effect Size
Personal Relevance	C	Pre	2.72	0.62	0.39
		Post	2.57	0.67	
	T	Pre	2.62	0.69	
		Post	2.80	0.69	
Agency	C	Pre	2.63	0.63	0.37
		Post	2.50	0.72	
	T	Pre	2.57	0.74	
		Post	2.75	0.75	
Emotional Connection	C	Pre	2.37	0.61	0.27
		Post	2.32	0.59	
	T	Pre	2.33	0.63	
		Post	2.48	0.66	
Content Confidence	C	Pre	2.65	0.65	0.31
		Post	2.62	0.71	
	T	Pre	2.67	0.67	
		Post	2.89	0.66	
Enjoyment of Science	C	Pre	2.78	0.61	0.28
		Post	2.68	0.65	
	T	Pre	2.71	0.73	
		Post	2.86	0.72	
Science Career Interest	C	Pre	3.92	0.68	0.36
		Post	3.81	0.73	
	T	Pre	3.93	0.62	
		Post	4.07	0.67	
Technology Career Interest	C	Pre	3.94	0.61	--
		Post	3.87	0.63	
	T	Pre	3.75	0.66	
		Post	3.85	0.69	
Engineering Career Interest	C	Pre	3.73	0.61	--
		Post	3.61	0.66	
	T	Pre	3.53	0.70	
		Post	3.57	0.72	
Mathematics Career Interest	C	Pre	4.03	0.54	0.23
		Post	3.90	0.76	
	T	Pre	3.79	0.70	
		Post	3.90	0.72	

Additionally, analyses were performed to look at differences in outcomes based on teachers' implementation of role modeling. Note that due to a large variance in the ways role models and role model videos were used by educators, it was not possible to analyze differences between the specific types of role modelling paradigms originally proposed in the project (CTE-STEM role model videos, near peer videos of girls interacting with CTE-STEM role models, videos made by girls for other girls, and in-person role model interactions). However, based on findings from the project's evaluation effort, treatment teachers were classified into four new role model groups: Live role models only (n=5), role modeling depicted through videos or reading articles (n=5), both (n=10), and neither – no role models used in classroom instruction (n=3). [4] These four groups were compared to each other and the comparison condition using a similar multiple regression model to the one described previously. (Total student sample size of 286). Only the seven outcomes for which there was a statistically significant treatment effect were examined. The goal was to better understand how the type of role modeling used may have influenced the effectiveness of the treatment.

In the analyses of all seven outcomes there was a statistically significant and favorable effect of using both kinds of role modeling representations (multiple regression; $p < 0.05$). See Table 2. Interestingly, for all seven outcomes there was also a statistically significant and favorable effect of using just live role models (multiple regression; $p < 0.05$). In four of seven outcomes, students of teachers using just live role models outperformed students of teachers using role models in videos or articles alone (multiple regression; $p < 0.05$). Similarly, in three of seven outcomes, using both kinds of role models was more beneficial than just using role models in videos or articles (multiple regression; $p < 0.05$). Taken together, the results suggest that there is an advantage to using role models in the implementation of SciGirls, and that advantage is largely attributed to the use of live role models.

Table 2. Comparisons of Role Modeling Type Across Outcomes; Statistically Significant Results Indicated by an "X"

Key Comparisons	Personal Relevance	Agency	Emotional Connection	Content Confidence	Enjoy-ment of Science	Science Career Interest	Math Career Interest
Both > Comparison	X	X	X	X	X	X	X
Just Live > Comparison	X	X	X	X	X	X	X
Just Video > Comparison							
Neither > Comparison	X	X			X		X

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[4] There were six treatment teachers for whom information about whether role modeling was incorporated into their implementation was unavailable. They were excluded for this analysis.

Both > Just Live							
Both > Just Video		X				X	X
Both > Neither			X				
Just Live > Just Video	X			X		X	X
Just Live > Neither			X	X			
Neither > Just Video		X					

Participants were also asked about their beliefs about science (science concept) before and after the intervention, as part of the Science Identity Scale. They were presented a list of responses and asked to select all that applied. Response patterns before and after are displayed in Table 3. As the table shows, students in the treatment and comparison conditions held similar beliefs before the intervention. Treating each option choice as an outcome, the changes from pre to post-intervention by group were analyzed using logistic regression. There were three statistically significant differences, all favoring the treatment group (logistic regression; p < 0.05). Students in the treatment group were more likely to hold the following beliefs after the intervention as compared to those who did not receive the intervention:

- Science is a process or method for investigating questions;
- Science is a special way of thinking about or viewing the world;
- Science is something I like.

Table 3. % of Respondents Selecting Each Response, Before/After the Intervention, by Treatment Group

		Percent Checked	
I consider science to be (select all that apply to YOUR opinion):		Comparison	Treatment
Knowledge, facts, or content	Pre	75	79
	Post	67	79
The group of people who do science	Pre	8	8
	Post	8	13
A process or method for investigating questions	Pre	71	71
	Post	56	78
A special way of thinking about or viewing the world	Pre	60	64
	Post	52	69
Something I like	Pre	46	53
	Post	40	57
Something I dislike	Pre	13	9
	Post	14	7

In summary, results show a significant program impact within 7 of 9 key composites of STEM-related identity based on the original research model. This indicates broad multi-dimensional growth of female students' STEM-related identity after exposure to SciGirls teaching strategies introduced by their teachers -- a definitive success of the program. However, it should also be noted that for each significant finding on the 7 composites, the effect sizes were relatively small. This may indicate the areas where the program is on the right track for impacting female students' sense of STEM-related identity, but poised to do better in maximizing those impacts through improved programming and/or more sustained efforts over time.

Especially compelling is the significant growth found in science concept after exposure to SciGirls teaching strategies over comparison groups (Science is a process or method for investigating questions; Science is a special way of thinking about or viewing the world; and Science is something I like). This shows a progress toward a more accurate view of what science is at the same time as more personal affinity to it, contradicting numerous prior findings that interest in science wanes as children age and their understanding of it becomes more abstract and complex. These encouraging results are strongly reflected in the case study findings presented in the next section.

A challenge to understanding which components of the program were more or less effective in bringing about this result is that there was no fidelity of implementation. That is, the project design included no provisional structure or requirements for what or how teachers who were engaged in the SciGirls professional development training would then utilize program elements in their classrooms. Rather, educators were left to their own counsel and experience in this regard – making the program less of a traditional "intervention" and more of an a-la-carte menu of teaching strategies. While arguably a positive feature of the professional development design (for example, it maximizes flexibility for educators), the result is a highly variable range of SciGirls-related classroom instruction strategies under investigation in this study, rather than a clearly defined intervention (see the project evaluation report for details on the impacts on teacher practice). It is also not possible to adequately examine the concert effect of multiple teaching strategies employed together or in sequence (the sum vs. the parts) that may be in play for student STEM-related identity development. It is worth noting that of the 17 educators whose students were in the treatment group, 6 of them represented the bulk of the significant findings -- with a range 10 to 65 respondents for each showing significant gains in all or most of the 7 key composites. Therefore a closer examination of the strategies employed by these educators by project leaders may be warranted.

Despite these challenges, the use of different kinds of role modelling was employed widely enough to draw some fascinating conclusions. First, role models matter, validating numerous other findings and ample practitioner wisdom. There is a distinct advantage in introducing female role models to female students in the context of student classroom experiences. Further, and perhaps not surprisingly, it appears that advantage lies more with in-person role

model interactions over video or article-reading based role model exposure. Also perhaps not surprisingly, any type of role modelling conferred advantages to STEM-related identity development over no role modelling. As discussed in the case studies in the following section, it appears even a single exposure to a strong female role model can positively impact female STEM-related identity development.

In the next section, multiple detailed case studies are presented to dive deeper into the mechanisms and personal experiences behind the different STEM-related identity development categories broadly examined in the quantitative investigation.

Qualitative Research

Case Study Methods
The team used individual case studies to investigate girls' personal learning experiences and individual meanings constructed from them, guided by the theoretical framework. Since the project sought insight on how girls make meaning and forge personal relevance from classroom strategies for equitable STEM experiences (to the extent of potential identity impacts), case study allows for the interpretive, descriptive depth needed to deal with the complexity of human interactions from a STEM-related identity theoretical perspective. The result is a set of six individual within-case analyses presented here along with a cross-case analysis.

The bounded system for this study was one semester in an urban high school where participants' teachers received SciGirls teacher training. There were three teachers and two STEM areas represented in the cases: biology and chemistry. There was no formal curriculum, activity, or intervention expected of the teachers (as noted above in the discussion of fidelity of implementation). Rather, they were left to their own counsel on whether and how to

implement SciGirls-related program elements. Of an original 14 girls participating in the case studies, 8 completed the requirements, and 6 were selected as final cases. The girls ages were 14-17.

Data sources for the case studies included:

- Multiple semi-structured (guided) interviews, dubbed the "Identity Interviews" which employed techniques and exercises based on prior social identity research;
- Journaling, using prompts and semi-structured format and;
- Autobiographical video narratives, using analysis techniques developed specifically for examining participant-created videos for identity research.

For case study data analysis, the design described by Stake (1995) was applied to formulate a detailed description of each case. These descriptions include case history, significant events and quotations, interpretations, and utilize a coding process (described below) to identify themes based both on the research questions and the theoretical framework. The *cross-case* analysis examined the emergent themes across all the cases to

identify the themes and meanings that seem to be shared among all participants and yield an understanding of what the SciGirls-related experience was like across all-cases, what made it important to their STEM-related identities (if it was), and how participants in their interpretation of their experiences, made meaning.

For coding, the team used thematic analysis techniques based upon identity theory and the theoretical framework, including: Agency (one's beliefs about their STEM performance/competence); Reflected self-appraisals (perceived recognition they receive from others in the context of STEM), and; Personal interest in STEM (including content confidence, emotional connection, personal relevance). And Behavioral outcomes including: Capacity (to engage in STEM); Understanding of STEM concepts; Attitudes and self-efficacy regarding STEM, and; Choices or future aspirations related to STEM.

For the analysis of participant-created autobiographical videos as data sources, the team used a narrative analysis approach developed by XSci that considers each video as a holistic story as well as a deconstruction of its elements in order to better elucidate the multi-dimensional meaning of the videos (McLain 2012). This approach is informed by previous approaches (Greene, Burke, & McKenna, 2018; Benmayor, 2008; Yussen & Ozcan,

1997; Clandinin & Connelly, 2000) and follows a coding strategy of multiple reviews (8 to 10) of each video to reveal themes: Visual coding to examine the imagery/visual themes chosen by the video creators (code-by-code and emergent); Verbal-linguistic coding of dialogue and/or narration based on a textual transcription of each video's audio and on-screen text (code-by-code and emergent); Analysis of the director's commentary as a self-interview in which video creators record a separate audio track with comments in real-time about their video-creation choices, decisions, and intentions; Scene-by-scene plot mapping to create a code-by-code conceptual map of each video to examine the order, content (including any music), salience, and code classification of each scene.

Pseudonyms were employed for all participants, their teachers, and other people mentioned.

Finally, it should be noted that this study was NOT program-centric; it was NOT intended to be a direct assessment of the SciGirls Strategies interventions or program-related resources, trainings, or student academic performance results. Rather, it was participant-centric; seeking to explore participant identity in development in the presence of SciGirls-related influences as part of the larger context of their lived experiences.

Case Study: Jane

Class: Chemistry

Profile

Jane was a 16 year-old high school sophomore in St. Paul MN at the time of the study. She is the oldest of four children and the only girl in her family. She enjoys art, reading hockey, music, cooking, and pottery. She also enjoys STEM subjects, learning new things, and applying STEM to her everyday life. She loves baking and blending it with science to increase her learning and create new things.

SciGirls Teacher: Ms. R,

1. Pre-Analysis (Initial Conditions at the start of the study)

A. Self Perceptions

At the beginning of the study, Jane described herself as a friendly, creative, and supportive leader. She did not consider herself to be selfish, ignorant, nor close-minded. When asked to list and rank her perceived identities, here were her responses:

Table 4: Jane's PRE Identity Sort

Importance	Time Spent as Each	Most to Least Pleasing	Ideal Self
1. Sister	1. Friend	1. Friend	All in one pile, and I'm queen of the universe
2. Friend	2. Student	2. Sister	
3. Avid reader	3. Sister	3. Avid reader	
4. Student	4. Avid reader	4. Hockey player	
5. Hockey player	5. Hockey player	5. Pet enthusiasm	
6. Pet enthusiast	6. Pet enthusiast	6. Student	

For Jane, STEM was included within her "Student" identity. And while she later stressed her love of baking and even used it as the subject of her video narrative, being a cook or baker does not appear on her identity list.

B. Role models:

During the pre-interview, Jane was very detailed in describing her role models. Here they are in order of importance:

- Her Mom: "She is Wonder Woman to me." She does data analysis, directs two teams, gets up at 6:00am daily, gets the family going each morning, works all day, takes care of everyone, and always stays positive.
- Grandmother: (mom's mom) and "where my mom gets her 'bad-ass-ery from.'" She was a nurse practitioner, and forged pathway in Massachusetts to allow fathers into delivery rooms when that was not an accepted practice. She also educated couples on birthing practices out her living room. "A super supportive person."

- Her Dad: Spent his life moving a lot, had five step-fathers growing up, later joined the Navy, now does everything to support education for his kids, learns alongside them in order to help them improve.
- Robert Downey Junior: Because he had a rough spot with drug abuse but turned his life around and became a "really good person."

Two of these role models relate strongly to STEM (Mom and Grandmother) and also overlap with being extremely personally relevant to Jane.

C. Conceptions of Science or STEM

Jane's conception of science was quite sophisticated, almost "textbook." She described science as the study of the world through experiments and modeled analysis. This hefty description was accompanied by a fairly robust understanding, as revealed in Jane's other reflections (presented below).

D. Self-Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

When asked if she considered herself to be "STEM person," Jane responded:

Kind of. I am someone who enjoys STEM and planning a STEM career. But I have no idea what I want to do with my life.
                              Pre-interview

When asked if others who knew her would consider her to be "STEM person," (reflected self-appraisal) she likewise responded, "kind of."

STEM Commitment

Emotionally, Jane described her relationship with STEM as variable, sometimes excited; sometimes confused; sometimes no emotion at all. On some days, she expressed great enthusiasm for STEM:

Science is the shit! Bill Bill Bill Bill Bill Bill Nye the science guy.
                              Journal

Additionally, she spent an estimated 15 hours per week on STEM and identified a social cohort around her STEM engagements of around four other students that she considered to be close friends.

2. SciGirls-Related Experience
(Experiences during the course of the semester)

A. Reflections

Like all the case studies, Jane's experiences with her particular teacher who was engaged in SciGirls training was blended and contextualized into a larger sphere of life experiences. Jane began with a highly functional and activated science perspective coupled with a moderately positive STEM-related identity. Notably evident in Jane's interviews, journaling, and video narrative was her scientific process literacy and scientific habits of mind -- a tendency to ask curious questions about the world and apply a scientific lens to them. For example, when discussing an incident in which her mother had baked cupcakes for the children Jane coached in hockey, she noted:

They were good cupcakes but didn't taste like they normally do. When I asked my mom about it she told me that the only butter she could find while baking was butter that had been sitting in our fridge for a while. Nobody got sick but I was wondering if it had to do with the butter's fermentation process in the fridge and how that could affect the taste.

Journal

Or this example:

What is the science behind having a crush on someone? What sort of chemical reaction does your body go through when your mind decides it likes another person?

Journal

Her overall engagement with STEM beyond her classroom experiences is summed up in the following journal entry:

Does STEM apply to me? Yes, most STEM subjects can be found in or applied to your everyday life. It's most often subtle but it applies in many ways.

Journal

Jane's SciGirls-trained teacher was Ms. R, whom she had for Chemistry. She described her in-class learning experience as fun, including a combination of projects, PowerPoint presentations, experiments, independent exploration, and homework. Her classroom was an open-learning environment with high interactivity and often innovatively incorporating arts and crafts within the science context. Her experiences in chemistry class correlated with her application of chemistry to baking -- the theme and focus of Kim's video narrative:

Why the science of baking? Baking is something I enjoy and do often. Breaking

down the things I make not only allows me to understand how the ingredients act and react with one another but I can use the knowledge to branch out sand create my own things.

Journal

Jane also indicated that Ms. R incorporated collaboration among students, personally relevant, hands-on and somewhat open-ended projects, positive and constructive feedback, and encouraged critical thinking in her class. These characteristics overlap with the elements that formed the backbone of the SciGirls educator training.

B. SciGirls Role Model Impacts

Jane identified no STEM role models being brought into the classroom by her SciGirls teacher, Ms. R. However, it is notable that for Jane, Ms. R herself served as a powerful STEM role model who had the ability to establish personal relevance and emotional connection to STEM that was likely not possible with anyone else:

Her [Ms. R] father just passed away from cancer and we were learning about cells at the time. She took like a whole day to tell us what had happened with her father and what's going on with herself -- because she has I-melanoma. And she talked about what cancer was and what it does to your body and I had an aunt pass away last January ... from cancer ... that stuck with me. I was glad she took the time to make sure we all knew what was happening. I was very grateful for that.

Post-interview

Later in the study, Jane began to refer to Ms. R as a friend she knew because of her STEM interests. Clearly, Ms. R was able to successfully link STEM learning to real life within the context of a chemistry class. In

this way, for Jane at least, she was able to powerfully bridge her role as teacher to one of role model as well.

C. Video Narrative Analysis

Jane's video narrative theme was that STEM is all around us everyday. The title was, "The S.T.E.M. and I: An Experimental Process." It included an introductory sequence set to a simple iMovie music track and explaining who she is, both related to and independent from STEM, including her love of reading, hockey, art, music, pottery, and baking. This was set over shots of groceries in a cart being pushed down the isle of a store, intercut with shots of her making pottery, followed by a brief discussion stating her perspective of STEM being embedded in everyday life all around us:

I enjoy STEM subjects. I just think they're a great way to reach out to new things and I think all STEM subjects can be found and applied in your everyday life. It's most often in subtle ways but it's really easy to find reasons how, like I did with my video about the science behind baking.

Director's commentary

The remainder of her video is an extended example of this idea through the science of bread baking. Within it, she seamlessly and repeatedly transitioned back and forth from a cooking tutorial to a science lab investigation -- all done there in her kitchen. It demonstrated both her science literacy (building heavily on her SciGirls-related chemistry class) as well as the personal relevance she perceived through her "STEM is all around us everyday" theme:

I decided to do that because baking is something that I do often and thoroughly enjoy. It not only allows me to understand just how baking just kind of involves science - not only through how the ingredients interact and react with one another -- but just how to branch out my knowledge and make me able so I can create my own new things.

Video narration

The scene-by-scene plot map provides an at-a-glance overview of the content and narrative nature of her video (Figure X). It includes a statement of purpose and/or information contained in each scene and was coded according to research model and then color-coded as follows:

1. Self Concept
- **Agency (self-efficacy)**
- **Content confidence (+attitudes)**
- **Role models**
- **Reflected self-appraisals**
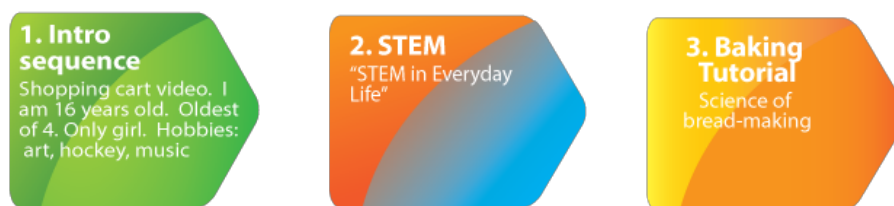
2. STEM Concept

3. STEM Commitment
- **Personal relevance & Emotional connection**
- **Peer influence & Community belongingness**
- **Aspirations**

4. STEM literacy (Capacity to understand and do STEM)

5. Choices (STEM related and peer related)

6. Time spent on STEM (behavioral vs. perceived commitment)

Figure 1: Jane's Video Plot Map

Note that Jane's video expresses four themes (shown in green, orange blue, and yellow): (1) Self-concept, including agency and STEM confidence, coupled with her most important role models; (2) STEM commitment, including mostly personal relevance and emotional connection; (3) STEM concept, through her perspective of STEM being all around us everyday, and; (4) STEM literacy as demonstrated in her bread baking tutorial sequence.

Interestingly, through her choice to include the cooking science tutorial, Jane also showcased a merging of her STEM-related identity with that of her "leader" identity, which emerged over the course of the study. By casting herself into an educator role for this sequence, she personified her emotional connection to STEM through something she loves to do, as well as her ability to communicate and share her theme of 'science around us everyday.'

3. Pre-Post Analysis

As described in the methods, the bounded time for the study was roughly one Spring semester of high school. For each case study participant, this marked the in-class learning experience they had with an educator who had just completed the SciGirls Educator training (described in the appendix). This pre-post analysis examines changes over that time period.

A. Self-Perceptions

Jane added "adventurous" and "ambitious" to her self-description over the course of the study. Listed below are the pre-post comparisons for Jane's perceived identities for the ranking of Importance and Time Spent as Each.

Table 5: Jane's Pre-Post Identity Sort

Importance PRE	Importance POST	Time Spent as Each PRE	Time Spent as Each POST
1. Sister	1. Friend	1. Friend	1. Friend
2. Friend	2. Sister	2. Student	2. Student
3. Avid reader	3. Daughter	3. Sister	3. Leader
4. Student	4. Leader	4. Avid reader	4. Daughter
5. Hockey player	5. Student	5. Hockey player	5. Girlfriend

6. Pet enthusiast	6. Girlfriend	6. Pet enthusiast	6. Sister
	7. Athlete		7. Athlete
	8. Artist		8. Artist

Jane added "Leader," "Daughter," "Girlfriend," and "Artist" to her list of identities over the term of the study. She also replaced "Hockey player" with the more general "Athlete," and dropped "Avid reader," and "Pet enthusiast" from her list. "Leader" features mid-way in her rank of importance (coming in at #4) while most of the others stayed roughly the same. Jane described her new "Leader" identity as linked to both her school life and being a leader in her classes and among her friends, and also with her home life as being the oldest of four siblings.

The other new identities were added to the end for both rank orders. In terms of time spent in each, her post-ranking was one she was not happy about, as it did not align well with her priorities as indicated in the importance ranking. As before, Jane's STEM identity was mostly integrated into her "Student" identity in these lists.

B. Role Models
Jane's list of most important role models Pre-Post were as follows:

Table 1: Jane's Role Models

Role Models PRE	Role Models POST
1. Her Mom (data analyst, Wonder Woman)	1. Her parents
2. Her Grandmother (nurse-practitioner)	2. Friends and teachers
3. Her Dad (supportive, co-learner)	3. Lisa Kudrow (who has both a science education and a life)
4. Robert Downey Junior (turned life around)	

Jane also lists the celebrity actress Lisa Kudrow citing that she earned a degree in science but still was able to explore other areas and potentials in life -- in this case, becoming a successful actress as well. This is something Jane admired.

attributed this awareness to Ms. R in her SciGirls-related class but also mentioned it

C. Conceptions of Science or STEM
Jane's conception of STEM changed a little over the course of the study to emphasize the notion of experimentation as a necessary process for learning and discovering new things. This is a critical component to a scientific worldview. She as a component of her experiences as a case study participant in this research:

It [SciGirls gatherings] has reinforced STEM is everywhere. We talk about all sorts of stuff at our SciGirls meetings and it's always fun. It's always interesting to hear other people's thoughts. It was a different setting than class was and I liked the fact that it was just girls. There's nothing wrong with boys -- it just gives us more of an opportunity to connect and related to one another.

Post-interview

Similar to what emerges in other case studies, here Jane observed some positive effects of having the case study participants gather weekly to work on their journals and video narratives. This is discussed further in the cross-case analysis.

D. Self Perceptions Related to STEM

STEM Agency and Self-Efficacy

Jane's perceived ability to understand STEM remained the same throughout the semester. Her perceived ability to participate in and contribute to STEM activities increased during the time of the study, indicating a higher degree of STEM agency, self-efficacy and content confidence. Her academic performance in terms of grades also remained high throughout.

STEM Commitment

Jane's STEM commitment and emotional connection also increased during the time of the study. She modified her emotional feelings about STEM from variable (sometimes excited, confused, or no emotion at all) to state that she now felt

Self-Appraisals and Reflected Self-Appraisals

Jane's self-appraisal as a "STEM person" changed to a definitive "yes" over the course of the study. Her reflected self-appraisal (whether others think of her a "STEM person") also changed from "kind of" to become more definitive, with this interesting statement:

Most would say 'no' just because the way I view STEM is it's in almost everything that you do. … I think a lot more about that now. You see more world context kind of stuff… I would definitely say the classes I've taken here have put it into a much bigger perspective, such as Ms. R's class.

Post-interview

Importantly, Jane makes a direct tie to her SciGirls-related classroom experiences with this comment. Although she possessed such a tendency or habit of mind to a scientific perspective at the beginning of the study, her classes with Ms. R (and others) reinforced it.
STEM was more important to her and that she was interested and curious about STEM. She also stated her interest in STEM increased over the course of the study because she:

Can see it in a bigger sense now. Ms. R helped me see it relate to everything -- a slow realization or lengthened a-ha moment.

Post-interview

Here again, Jane explicitly credits her SciGirls-trained educator with contributing powerfully to her ability to recognize STEM in everyday life and this change in her STEM-related self-perceptions. She points out that this was a gradual but significant transformation.

Given her newly acquired perspective on STEM, when asked about her biggest challenges and frustrations regarding STEM, she observed that it was that STEM is not always exact. But it is a frustration she framed positively:

So the whole thing with science is that there is like no correct answer, right? And so it's about what you learn and what you find. I love that, but at the same time it's kind of like I like knowing that there's some form -- like math … there's ways to make sure you get a correct answer.
<div align="right">Post-interview</div>

Interestingly, the time she estimated spending on STEM each week dropped over the course of the semester from 15 hours to 8 -10 hours, however at the time of the post-interview (near the end of Spring semester) she had a lighter load for most classes. Her perceived ability to become excited about STEM learning remains high throughout the study and her social connection to STEM remained consistent, with two to four close friends in STEM.

Finally, Jane evolved her aspirations over the time of the study from having none, to:

Travel, definitely something in science, mid-wife, pharmaceuticals maybe.
<div align="right">Post-interview</div>

E. Survey Results
A more in-depth discussion of case study participant survey results will be completed when the final overall quantitative study is complete.

Note: Jane completed the VNOS survey as pre and post but did not complete any other post-surveys for comparisons.

Science Identity Scale
Pre: 3.0

Girls Interest in Nature and Science Scale
Pre: 3.9

STEM Career Interest Survey
Pre: 3.9

VNOS: Novice, min to mod growth

Science can be many things, but mostly it is a process of experimentation and learning.
<div align="right">P   VNOS-post</div>

4. Discussion

With Jane, we see a girl who begins with a fairly positive STEM-related identity but deepens and strengthens her STEM self-perceptions through the course of the semester. Her existing positive STEM-related identity was reinforced through her experiences in her SciGirls-related chemistry class with Ms. R, whom she also considered to be a friend and de-facto role model. Her STEM-related self-appraisal and her reflected self-appraisals both became more definitively positive as a result of her in-class experiences. Her STEM concept became more refined through in-class experiences to include the notion of learning through experimentation. Her perceived ability to participate in STEM increased and her socio-emotional connection to STEM grew over the course of the semester.

Most of the reinforcement of her STEM-related identity development, however, fell under the category of establishing greater personal relevancy for STEM by opening her eyes to STEM all around us,

everyday -- also the theme of her video narrative.

Additionally, as Jane was increasingly able to see STEM in her everyday life, she began to apply her existing curiosity to more scientific habits of mind, both in the ways she framed questions and in what she framed question about. Scientific questioning became applicable to

everything for her. At the same time, Jane's conception of science and STEM was expanded along with her self-perceptions of how it was relevant to her. In terms of the effects of SciGirls educator training, it is clear that Ms. R, employing most of the practices identified in SciGirls training, was able to facilitate important STEM-related identity gains for Jane.

Case Study: Laura

Profile

Laura was a 14 year-old high school student in St. Paul MN at the time of the study. She enjoys nature, being a daughter, a friend, and a teammate in sports. She also loves STEM.

SciGirls Teacher: Ms. R,
Class: Biology

1. Pre-Analysis (Initial Conditions at the start of the study)

A. Self Perceptions

In talking about herself at the beginning of the study, Laura emphasized her relationship with nature as a way to combine her passion for the outdoors with her love of STEM. Conservation is an important motivator for her and she has been active in preserving the natural world in large and small ways. She also does volleyball, photography, reading and writing. She does not, however, consider herself to be artistic, extroverted, or someone who takes "quick action" in any situation. When asked to list and rank her perceived identities, here were her responses:

Table 2: Laura's PRE Identity Sort

Importance	Time Spent as Each	Most to Least Pleasing
1. Daughter & Friend (tied)	1. Needer	1. Adventurer
2. Adventurer	2. Confused	2. Learner
3. Learner	3. Consumer	3. Friend
4. Needer	4. Friend	4. Daughter
5. Comforter	5. Daughter	5. Conservationist
6. Student	6.Student	6. Comforter
7. Athlete	7. Athlete	7. Writer
8. Teammate (volleyball)	8. Reader	8. Reader
9. Giver (advice)	9. Peer	9. Discoverer
10. Confused	10. Owner	10. Dreamer
11. Conservationist	11. Learner	11. Athlete
12. Listener	12. Giver	12. Listener
13. Taker (of help)	13. Photographer	13. Teammate
14. Consumer (over-consumer)	14. Dreamer	14. Photographer

15. Peer	15. Explorer	15. Giver
16. Explorer	16. Listener	16. Explorer
17. Owner (my things) (materialist)	17. teammate	17. Helper
18. Discoverer	18. Helper	18. Hoper
19. Reader	19. Comforter	19. Student
20. Helper	20. Taker	20. Confused
21. Hoper	21. Hoper	21. Peer
22. Dreamer	22. Adventurer	22. Taker
23. Writer	23. Conservationist	23. Owner
24. Photographer	24. Discoverer	24. Needer
	25. Writer	25. Consumer

Laura produced a lengthy list of identities, reflecting a highly multi-dimensional and self-aware concept of Self. Many of her identities were connected to her passion for conservation and her exploration of this topic. For example, being an "Owner" of things and a "Consumer" are both related to her "Conservationist" identity, but in a negative way. She does not like these things about herself but acknowledges them as part of who she is. Clearly she had done some reading and deep thinking on this topic and how it personally relates to her, her lifestyle, and her choices. Of note, five of her identities clearly deal with Laura's STEM-related identity: "Conservationist," Learner," "Student," "Explorer," "Discoverer." The last four feature Laura's spirit of inquiry that she employs in nearly every facet of her life.

B. Role models:

During the pre-interview, Laura listed her role models. It was a ready-made mental list that she keeps and dubbed her "hero list." Her they are in order of importance:

- 2nd Grade teacher Mr. Carver: Influential, "cool," and "insanely kind," involved in school patrol, a fossil dig in Iowa once, travelled to Africa to help build a school, Laura strives to be like him -- his "whole personality."
- Sigrid Olson (author): For his books on environmentalism, she shares his outlook on the world.
- Parents: Because they are really relaxed, "easy come, easy go" and are able to "handle stuff," which she aspires to do as well.
- Best friend Angel: For the same reasons at her parents and for Angel's theory of "do what you can for the story because that's all we have in the end."
- Mysterious #11, She is a junior in high school, volleyball player on another team: "Because she's so committed," which Laura also

aspires to be no matter what the topic or activity.

Two of these role models relate strongly to STEM: Her 2nd grade teacher who engages in STEM activities and with whom she is still in contact; and the author Sigrid Olsen who wrote about and active in environmentalism, conservation, and caring for the natural world.

C. Conceptions of Science or STEM

Laura's conception of science was fairly simple and straightforward:

> *[Science is] the exploration of what we don't know to find out what we do.*
> Pre-Interview

Doing science means, she said, is the process of figuring things out in a continuous cycle:

> *I believe its nothing really definite. That's what my 8th grade science teacher told me -- that there's a whole recycle of information. Sometime ago everyone was convinced the truth is the world was flat and now it's that it's round. And what people believe now probly will be disproven in the future and that will be disproven again and it's just trying to figure out what's going on.*
> Pre-Interview

This conception is science is somewhat unclear murky. It affirms the exploratory nature of science but without awareness of its methods and processes. However, the idea of the cycle of science as a feature reflects good introductory STEM learning experiences.

D. Self-Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

Laura entered the study considering herself to be "STEM person" because she enjoys and is interested in STEM and involved in STEM activities and learning. To Laura, asking questions was almost the equivalent of doing STEM, and she made a habit of doing so as part of her normal thinking:

> *I've always asked questions. I mean I've asked my teachers questions they can't answer, especially like HOW things got figured out.*
> Pre-Interview

> *"How" is my favorite science question. It's what I always want to figure out.*
> Journal

> *While watching a video in biology, I had to wonder about the videography involved in the natural world. How are these amazing videos taken without disturbing the wildlife or having them run or fly away? Even these parts of science amaze me.*
> Journal

In terms of STEM, she stated that she did not like math as much as science, but realized that she had to learn math in order to pursue her passion for science.

For her reflected self-appraisals (whether she thought others think of her as a "STEM person"), she perceived that others (friends and family) think of her as a "STEM person" as well. Interestingly she indirectly commented on STEM-related stereotypes with this statement:

> *My friends think that I'm a STEM person. And when I told my friend I was coming here to do this (the SciGirls research interview), she said 'Oh man, you're a*

genius' or something like that. I'm like 'I'm just interested,' it's OK. And my parents are probly annoyed by all of my questions (laughs).

<div align="right">Pre-Interview</div>

In this case, being labeled a "genius" because she is interested in STEM was not necessarily a compliment, nor was the comment about annoying her parents with endless questions about how the world works. Yet she discussed both with a laugh and a smile, indicating she was aware of the stereotypes associated with STEM but did not let that stop her from being unabashedly a "STEM person."

Although highly engaged and interested in STEM, Laura initially rated her ability to understand STEM concepts at only moderate. Regardless, she rated her ability to participate and contribute to STEM activities as high.

STEM Commitment
Laura estimated she spent 15 to 17 hours on STEM each week. She routinely reads non-school-related STEM oriented books and described her out-of-school STEM activities as:

I conduct my own science research and do photography.

<div align="right">Pre-Interview</div>

She also identified a group of five or six friends she knows because of her STEM engagement. Three of these she considered close friends, indicating influential social support for her positive STEM-related identity.

2. SciGirls-Related Experience
(Experiences during the course of the semester)

A. Reflections
Like all the case studies, Laura's experiences with her particular teacher who was engaged in SciGirls training was blended and contextualized into a larger sphere of life experiences. Laura began with a highly positive STEM-related identity that was closely tied in with her identity as a conservationist. Her journal entries indicated a highly reflective, frequent, and pondering self-discourse that often centered on the natural world:

I was feeling very detached the night before the 1st meeting [of the SciGirls case study participants]. This led to a strong longing for the natural world that I, and most of the world, have been deprived of for so long. The word 'save' makes you sound like a hero, but to 'save the Earth' would not be an act of heroism but an act of recovery. It's your job from the start. You're the villain in the story, not the hero. Everyone hurts the same earth.

<div align="right">Journal</div>

Laura's SciGirls-trained teacher was Ms. R, whom she had for Biology. She described her in-class learning experience as interactive and hands-on, including doing labs, exploring real world examples, and even role-playing as carbon molecules in the classroom. She liked and appreciated this approach to learning biology, which was tied to her extra efforts to get good grades, "especially in that class," as she put it.

Laura also observed that as the semester went on, Ms. R changed her classroom practice slightly to spend more time one-

on-one with students versus always addressing the whole class. She noted that Ms. R also made efforts to explain the science content in different ways to different students during these interactions in order to best facilitate understanding, recognizing different students may need different approaches or different examples. This differentiated learning strategy was included in the SciGirls educator training as a technique for facilitating personal relevancy.

Notably, her experiences in biology class correlated with her application for a Global Leadership Adventures program to do work on turtle conservation science in the Galapagos Islands over the following summer:

I hope so much that I go to this to learn about the science involved in conserving these amazing places. I only wish I could incorporate videos of my trip into my SciGirls event.

Journal

It was revealed in her post interview that she was indeed accepted into the program, which was to last two weeks and include the natural geologic history of the islands as well as the biology and conservation of Galapagos tortoises.

Fulfilling her self-described role as an 'Asker,' Laura was very interested in the reasons behind the SciGirls research effort itself, and wanted to discuss this on multiple occasions. Upon some reflection, she offered the following in her journal:

It's not that school itself is hard. It's that sometimes it's very difficult to find the time for everything. I want to do well in school and volleyball and volunteer work and be involved in science, but there's minimal

time. I think that's why the whole case study is about why in high school girls lose interest in science. I'm sure boys do too because we all have a lot less time. And for people who find an interest in science but aren't obsessed with it, they might have to put it out of their lives to make room for increased schoolwork, sports, and stress. It's hard to do it all.

Journal

This notion of competing responsibilities, interests, and activities that may inhibit STEM pursuits or create barriers for entry into a consideration of STEM as a potential interest for students is important. Laura recognizes that she has a strong positive STEM-related identity and lots of support and personal commitment to STEM. Yet she can also see that for students who are more casually interested in STEM or have not yet reached a point of being ready for a greater commitment to STEM, the chances they will have time to develop that casual interest and mature it, is slim. Laura herself resolved this issue by developing a strong positive STEM-related identity early and maintaining it as a 'normal' priority in the swim of other demands on her limited time and energy.

B. SciGirls Role Model Impacts

Laura identified no STEM role models being brought into the classroom by her SciGirls-trained teacher. However, she did state that they often discussed the stories of historical scientists in addition to other biology content alone. For example, Laura mentioned studying the story of Watson and Crick, who are famous for articulating the structure of DNA, but largely based their work on Rosalind Franklin's ideas -- who almost nobody remembers. She also mentioned the posters that Ms. R had up in

the classroom depicting women in STEM role models and career options.

C. Video Narrative Analysis

Laura's video narrative started off with this statement:

Hi, my name is [Laura]. I'm a student. I 'm a daughter. I'm a friend and a teammate. And part of me is in love with STEM.
                                    Video Narration

Her central theme was the unification of her love for nature and conservation with STEM learning. Throughout her short video, she presented a holistic and seamless integration of these passions along with elements of her life that are important to her. In segueing from her slice-of-life intro scenes, she bridged her habit of constantly asking questions about the world around her, to environmentalism, to STEM:

My passions have changed since I have grown, I've always been extremely curious. I've always wondered about the world around me; why things are the way they are. Why that rock ended up where it is and not three feet to the left. Why that river runs the way it does and not something else. Why animals and people and even machines do the things they do. Questions have always been a constant part of my life. And once I reached middle school, even my science teachers couldn't answer the complex questions I had about science and the natural world.
                                    Video narration

Though simple and brief, Laura's video narrative worked powerfully as an extended identity declaration, showing her adventures in nature, stating her conservationist values, and explaining

how STEM (biology in particular) informs and enriches her life:

I always wonder about what's happening in our world and what I can do about it. I'll spend my free time researching topics like ocean acidification and deforestation. This interest has given me an extreme love for science. Everywhere I look, nature and the wilderness is filled with biology and science. And the only way to keep the wild alive is through science.
                                    Video Narration

Her video also depicted her involvement in the science march on Earth Day, 2017. As she stated in her Director's commentary:

I also decided to include a couple [video clips] from the science march on Earth Day. I thought that that would show my interest in the scientific community and how I'm taking action in what I believe in.
                                    Director's Commentary

Importantly, in this sequence, Laura is tying together her passions for environmental conservation and STEM, and then connecting both to her experience in biology -- a class that has clearly influenced Laura's thinking. However, she also reflected on her passion for learning sometimes being at odds with her school experiences:

Learning has always been a highlight of my life, but school always hasn't. Just like any other student, I get stressed and have trouble coping at times. Slowly, I'm learning how to deal with this. I've recently come to the realization that my life is full of challenging moments. And everyone is tested on their perseverance at some point or another. And I think as long as I can stick with what I love, I'll do just fine.
                                    Video Narration

In the ending outro scene, Laura summed up her hopes for her video in her Director's Commentary:

Overall, I hoped my video conveyed a sense of my personal being and how that is connected to nature, and how it might be connected to it in the future and as well as science.
Director's Commentary

The scene-by-scene plot map provides an at-a-glance overview of the content and narrative nature of her video (Figure X). It includes a statement of purpose and/or information contained in each scene and was coded according to research model and then color-coded as follows:

1. Self Concept
- **Agency (self-efficacy)**

- **Content confidence (+attitudes)**
- **Role models**
- **Reflected self-appraisals**

2. STEM Concept

3. STEM Commitment
- **Personal relevance & Emotional connection**
- **Peer influence & Community belongingness**
- **Aspirations**

4. STEM literacy (Capacity to understand and do STEM)

5. Choices (STEM related and peer related)

6. Time spent on STEM (behavioral vs. perceived commitment)
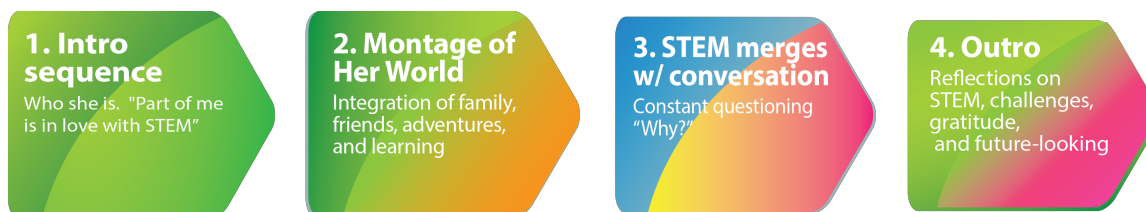

Figure 2: Laura's Video Plot Map

Note that her video expressed four themes (shown in green, orange blue, and pink): (1) Self-concept, including agency and STEM confidence; (2) STEM commitment, including mostly personal relevance and emotional connection; (3) STEM concept, through her perspective of STEM connected to conservation and; (4) STEM-related choices.

Laura's portrayal of her life, infused with nature and STEM learning, is centered on the science of biology and the course taught by her SciGirls-trained educator.

These themes reflect a pathway Laura has forged to translate her in classroom STEM experiences into her own world outside of school, where she has greater control and agency.

There was no music in Laura's video narrative, only her narration. There also were no scenes in her video of school, her teachers, or her biology class, suggesting that her most personally relevant STEM-related identity construction is taking place out of school -- but informed and influenced by her classroom experiences.

3. Pre-Post Analysis

As described in the methods, the bounded time for the study was roughly one Spring semester of high school. For each case study participant, this marked the in-class learning experience they had with an educator who had just completed the SciGirls Educator training (described in the appendix). This pre-post analysis examines changes over that time period.

A. Self-Perceptions

Listed below are the pre-post comparisons for Laura's identity list for the ranking of Importance and Time Spent as Each.

Table 3: Laura's Pre-Post Identity Sort

Importance PRE	Importance POST	Time Spent as Each PRE	Time Spent as Each POST
1. Daughter & Friend (tied)	1. Friend	1. Needer	1. Needer
2. Adventurer	2. Daughter	2. Confused	2. Student
3. Learner	3. Adventurer	3. Consumer	3. Player
4. Needer	4. Conservationist	4. Friend	4. Teammate
5. Comforter	5. Idealist	5. Daughter	5. Asker
6. Student	6. Volunteer	6.Student	6. Stressful
7. Athlete	7. Asker	7. Athlete	7. Daughter
8. Teammate (volleyball)	9. Teammate	8. Reader	8. Thinker
9. Giver (advice)	8. Guide	9. Peer	9. Friend
10. Confused	10. Reader	10. Owner	10. Idealist
11. Conservationist	11. Helper (to people)	11. Learner	11. Helper
12. Listener	12. Thinker	12. Giver	12. Reader
13. Taker (of help)	13. Player	13. Photographer	13. Peer
14. Consumer (over-consumer)	14. Needer (food, water, friends, support)	14. Dreamer	14. Sleeper
15. Peer	15. Sleeper	15. Explorer	15. Volunteer
16. Explorer	16. Peer	16. Listener	16. Adventurer
17. Owner (my things) (materialist)	17. Student	17. teammate	17. Conservationist
18. Discoverer	18. Stressful	18. Helper	18. Guide
19. Reader		19. Comforter	

20. Helper		20. Taker	
21. Hoper		21. Hoper	
22. Dreamer		22. Adventurer	
23. Writer		23. Conservationist	
24. Photographer		24. Discoverer	
		25. Writer	

With an identity list this long, it is difficult to remain precisely consistent over time. Additionally, participants are not provided their prior set of identity sort cards to re-use. Rather they are asked to generate new responses expressly for the purposes of comparison. Here with Laura, we see a number of post-sorting modifications to her identities compared to her prior list. However, both lists are notably multi-dimensional and self-aware. The identities of "Owner" and "Consumer" dropped off the post list -- the two identities Laura expressly did not like. As well, "Hoper," "Dreamer," "Writer," "Photographer," and "Confused" dropped off the post list, while "Idealist," "Asker," and "Volunteer" were added.

Interestingly, she ranked "Student" at the bottom of her ranking for importance. Along with her other comments regarding struggles in school, this may indicate that her love of learning is mostly experienced outside of the school setting. Yet she also observed that her learning in biology class informed her independent learning out of school, in nature, and through special programs such as the GLA program she was accepted into in the Galapagos.

B. Role Models
Laura's list of most important role models Pre-Post were as follows:

Table 4: Laura's Role Models

Role Models PRE	Role Models POST
1. 2nd Grade teacher, Mr. Carver	1. 2nd Grade teacher
2. Sigrid Olson, environmental author/activist	2. 8th Grade earth science and forensics teacher, Ms. Linus
3. Her parents, relaxed but supportive	3. Her parents, for having adventures and a successful life
4. Angel, best friend	4. Sigrid Olson, idealist view of individuality
5. #11 of opponent volleyball team for level of commitment	5. Angel, best friend
	6. #11 of opponent

	team

Laura added her 8th grade science teacher here for her patience with and encouragement of Laura's tendency to ask many questions, including hard questions. Prior to this teacher, Laura reported that she received mostly intolerance and dismissal from her friends and teachers for asking STEM-related questions.

None of her cited role models resulted from experiences in her SciGirls-related biology class. However, as discussed above, her explorations of women scientists in her biology class did have a positive impact on Laura.

C. Conceptions of Science or STEM

Laura's conception of STEM (science in this case) evolved and became more sophisticated over the course of the study. From what she stated it in the pre-interview:

> *[Science is] the exploration of what we don't know to find out what we do.*
> Pre-Interview

To the following in the post interview:

> *I would define science as a study of unexplained things to try and get a greater understanding by finding the most logical conclusion based on evidence.*
> Post-Interview

In course of one semester, Laura expanded upon her prior conceptualization of science to include the idea of forging understanding based on logic and evidence -- a central tenet of scientific investigation.

D. Self Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

Laura's self-appraisal as a "STEM person" remained un-changed over the course of the study. Her reflected self-appraisal of whether she thinks others think of her a "STEM person" also remained unchanged -- both unambiguously affirmative.

STEM Agency and Self-Efficacy

Laura's perceived ability to understand STEM increased slightly over the course of the study, as did her perceived ability to participate in and contribute to STEM activities, indicating a higher degree of STEM agency, self-efficacy and content confidence. Laura's academic performance in terms of grades also remained high throughout.

Interestingly, Laura pointed out that her recent success in volleyball has also contributed to her sense of STEM agency:

> *I recently gained a lot of confidence in my playing ability for volleyball ... It [recent tournament play] was this big confidence boost for me, like, 'hey, I can actually do this. I know what I'm doing. This is my sport.' Recently our coach asked us, 'would you rather play with someone who was lacking self-confidence or cocky?' And we were, like, 'oh, probly someone lacking self-confidence.' And then later on we've learned that being a little cocky doesn't have to be bad because it gives you the confidence to, like, do things you wouldn't normally do. That might be where I'm at right now. I took an AP test and I didn't do*

well on it and … I'm not having the anxiety I feel I would normally have with that. And maybe that transfers to like now I've been thinking about how maybe my junior and senior year I should try and take multiple science classes. My friends are like, 'you're not gonna want to do that,' and I'm like, 'no no no, I can do it now.' Before I was like, 'oh maybe they're right,' but now it's like, I think I can do it.

<div align="right">Post-Interview</div>

This observation is a fascinating example of harmonious identity overlap. Laura's identity and successful role performance as a volleyball player complimented her STEM-related identity in a positive way and even transferred agency to Laura's self perceptions as someone who can do STEM. The result was that Laura was willing to take greater intellectual risk in signing up for more science classes in the future.

STEM Commitment

Laura's STEM commitment and emotional connection to STEM remained high through the study:

[I feel] proud saying I can be part of it [STEM], and saying I can be part of, like, this group of people who've figured out all these great things. And then also excited because I know I'm going to be more involved in the future.

<div align="right">Post-Interview</div>

Laura's comment indicates an awareness and satisfaction about belonging to the social community of "STEM people" and communicates her excitement in anticipation deepening that connection. This supplements her concept of what STEM is to also include who does STEM and her sense of validation and social identity with that group.

Her main frustration with STEM remained the same as well -- math.

The time she estimated spending on STEM each week increased from approximately 17 hours to an estimated 35 hours, due to an increase in both her personal pursuit and STEM-related reading at home as well as increased homework load.   Laura's social connection to STEM through five or six friends remained the same over the course of the study.

Finally, Laura modified her career aspirations over the time of the study from, "Commercial airline pilot or oceanographer or environmental law or FBI agent" to a broader description:

I know I don't want an office job no matter what. So probably doing some sort of research in a lab or building up to working in a lab -- a research assistant.

<div align="right">Post-Interview</div>

She still includes becoming a pilot as well in her list of aspirations.

E. Survey Results

A more in-depth discussion of case study participant survey results will be completed when the final overall quantitative study is complete.

Science Identity Scale
Pre: 3.3
Post: 3.6

Girls Interest in Nature and Science Scale
Pre: 3.6
Post: 4.0

STEM Career Interest Survey
Pre: 3.5

Post: 4.2

VNOS: Novice, consistent, min to mod growth

Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future?:

Science constantly fluxes based on available evidence. If u have a limited amount of evidence then u must make a limited conclusion as technology advances more evidence arises"

How is science different from the other subjects you are studying?

It is based on evidence and it's fun.

VNOS - Post

4. Discussion

With Laura, we see a passionate STEM enthusiast -- prior to, during, and at the conclusion of the study -- whose STEM-related identity grew even more positive as a result of several factors, including her experiences in Ms. R's SciGirls-related biology class. Laura's pathway to STEM was conservation related to biology and environmental science. This was the means by which she was able to forge a high degree of personal relevance to STEM and it was the means by which this relevance was reinforced throughout the semester.

Laura also demonstrated a high capacity for wonder and curiosity for the world around her, unafraid to ask hard questions and to pursue her answers. Notably, she indicated that her earlier tendency to do this in school was discouraged; so she developed this part of her identity out-of-school through her own hobbies, reading, explorations, and friendships. However, this began to change with her 8th grade earth science teacher, whom she also identified as an important role model for her. She was able to show patience for Laura's hard questions and even encourage them.

From that time on and with the support of more science teachers, Laura was able to increasingly blend her in-school and out-of-school STEM pursuits and thereby mature and solidify her STEM-related identity. This influence of role models and supportive teachers is a critical component in Laura's development and although it started relatively late, had already resulted in a deep and validated passion for STEM and participation in exciting extracurricular STEM learning, such as the Galapagos summer research experience. Finally, we learn from Laura's case about an interesting harmonious identity overlap between her role performance as a volleyball player and her STEM-related identity. It is an example of positive inter-identity reinforcement. It resulted in Laura considering taking more STEM-related risks and adopting a greater growth mindset. It is also not hard to imagine how this same effect can swing negative for children who are invalidated in one important identity and see a ripple affect into others. In the end, Laura's experiences in the Spring semester, including her SciGirls-related learning, verified her existing STEM-related identity and enhanced it.

Case Study: Kim

Profile

Kim was a 15 year-old high school sophomore in St. Paul, MN at the time of the study. She is the middle child of three, all girls, with both parents living at home and both of them college STEM professors. She is a highly motivated athlete and student, of Caucasian descent, and loves reading, hiking, photography, and most of all Nordic skiing.

SciGirls Teacher: Mr. C.
Class: Chemistry accelerated

1. Pre-Analysis (Initial Conditions at the start of the study)

Table 5: Kim's Pre Identity Sort

Importance	Time Spent as Each	Most to Least Pleasing	Ideal Self
1. Daughter	1. Skier	1. Skier	1. Daughter
2. Sister	2. Lover of school	2. Reader	2. Sister
3. Good friend	3. Sister	3. Daughter	3. Good Friend
4. Skier	4. Daughter	4. Upbeat person	4. Upbeat person
5. Upbeat person	5. Good friend	5. Good friend	5. Skier
6. Lover of school	6. Upbeat person	6. Sister	6. Reader
7. Reader	7. Reader	7. Lover of school	7. Lover of school

Interestingly, Kim listed "Skier" mid-way down the list in terms of importance, after family and friend identities that she considered higher priorities. "Skier" topped the Time list, however, as the identity she spent the most time in. Notably regarding her STEM identity, upon probing Kim included STEM in both her "Lover of school" identity when it related to her in class STEM learning, but

A. Self Perceptions

Kim initially described herself this way:

I am a lover of nature and photography. My identity is closely linked to my love of science and Nordic skiing.
Pre-Interview

She considered herself kind, not lazy or unmotivated, someone who loves reading and school but identifies the most with skiing. When asked to list and rank her perceived identities her responses were:

also in her Nordic skiing. She discussed how she thinks a lot about and would like to learn more about the science of skiing (types of snow, ski shape, waxes and effects, techniques) as a way to combine her passions for both.

B. Role models:

During the pre-interview, Kim listed her role models in order of importance as follows:

- Her parents: Both college professors in STEM (mom in microbiology and dad in computer science) and responsible for including STEM in her life as something normal and accepted.
- One of her ski coaches: Who also happens to be an astrophysicist and therefore inspires her in both domains.
- Her older sister: Who is in college studying political science and computer science.

Notice that all three of these role models relate strongly to STEM and also overlap with being extremely personally relevant to Kim.

C. Conceptions of Science or STEM

Kim's concept of science was simple:

Science is study of living things. It's more expansive than that, but I always think of biology when I think of science.

For biology, this was of course is an accurate general description. Her awareness of science being larger than the field of biology is there, but does not yet seem to encompass what she loved about (or gets excited about) science.

She further unpacked the idea of *doing* science in this way:

Doing science is learning what someone else discovered. I 'm just reviewing and reframing in a different way.

She added that someday perhaps she would be involved in direct discovery, but felt that this was not accessible to her in her current classes.

D. Self-Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

Kim began the semester with a moderately positive and relevant STEM-related identity. During the pre-interview assessment of her self-appraisal, she acknowledged that she thought of herself as a "STEM person," stating again that she "loved bio" and was "trying to get interested in computer science." (Pre-Interview).

She rated her ability to understand STEM as high and her ability to participate and contribute to STEM activities as high, indicating a high sense of STEM agency and confidence.

When asked if others who knew her would consider her to be "STEM person," (her reflected self-appraisal) she hesitated, guessing that most of her friends would not think of her in this way and that even in her own family she was known more as a reader (apparently distinct from being a STEM person). The only possible exception, she observed, was her mom, who might know that she was interested in STEM.

STEM Commitment

Emotionally, Kim expressed that biology made her happy but that math made her mostly frustrated. She rated her ability to get excited about STEM in general as high. She estimated the time she spent on STEM activities and learning at about 15 hours

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per week. Her social connection to STEM was low but important to her; she counted two of the people she knew through STEM as close friends. Finally, Kim described her initial career aspiration as, "biology-something" (Pre-Interview).

2. SciGirls-Related Experience
(Experiences during the course of the semester)

A. Reflections
Like all the case studies, Kim's experiences with her particular teacher who was engaged in SciGirls training was blended and contextualized into a larger sphere of life experiences. For Kim, this background context of her STEM-related identity development is important for understanding the impact of her experiences during the SciGirls project.

When asked to focus on her STEM learning experiences and the SciGirls project as a case study participant, Kim chose to incorporate her reflection into a narrative extending back to elementary school years and through what she called "a roller coaster ride with science" in the face of several ups and downs. In the end, it has something important to teach us about the struggle to develop and maintain a positive STEM-related identity.

To begin with, both of her parents were college professors in STEM fields, making science an everyday part of her early life. Throughout school, she developed an increasingly positive STEM-related identity. As she wrote in her journal:

I enjoyed science through elementary school... [but later] I was ready for something more advanced.

Journal

Her passion for science really ignited in 7th grade genetics class, where "everything clicked for me," as she put it:

In 7th grade I loved science. I was finally able to explore the things I had always had questions about.

Journal

But her newfound love for biology was quickly followed by an 8th grade physical science class, which she hated. Notably, she specifically called out that she hated the teacher; suggestive of how closely perceptions of STEM can be tied to the personality of the educator. She emerged with her interest in STEM intact enough to become excited STEM-excited again by 9th grade:

I had never been interested in earthquakes or anything like that. That year [8th grade] wrapped up and my passion for science was still alive. My 9th grade year I took biology. I loved everything we learned about. I especially loved learning about cells. I was amazed at how something so small could make up my whole body. I sped through biology always wanting to learn more. My 9th grade year ended on a happy note.

Journal

While her experience in 8th grade was her first bitter taste of science, it was not to be her last. Throughout her journal entries, which she used as draft scripts for her video narrative, Kim continued to struggle to express her STEM-related identity development in positive terms amidst her ongoing personal battle with negative STEM experiences, including her SciGirls-related 10th grade chemistry class:

This year [sophomore, age 15] has been much harder… I don't enjoy chemistry as much as I enjoyed biology. To keep myself motivated I had to focus on other subjects in school.

<div align="right">Journal</div>

Kim described her SciGirls-trained teacher, Chemistry teacher 'Mr. C,' as running a very self-directed class that somewhat de-emphasized notes and lecture, and instead stressed doing labs where students were given the basics and then left to make leaps of understanding for themselves.   When asked if that teaching style worked for her, Kim said:

It was unique. It was OK. I get good grades, but I don't enjoy it. It's hard to connect to real world situations.

<div align="right">Post-Interview</div>

When asked if she like her chemistry class she said:

Chemistry has not been my favorite subject. I really loved biology and I'm having a harder time applying chemistry to my personal life, even though, I mean, your body has so many chemical reactions going on. I haven't been as a big of a fan.

<div align="right">Post-Interview</div>

This lack of personal relevancy translated to a struggle to stay motivated. Eventually however, she stuck it out and completed the course.

I got through the year knowing that chemistry is important to my education. My roller coaster ride with science has taught me being motivated when it comes to academics is extremely important. Enjoying high school is very important to my happiness. Science is an integral part of society that I love.

<div align="right">Journal</div>

In these excerpts, Kim is working hard to frame her negative chemistry experience in a positive light, while also recognizing and emphasizing how difficult it is to persist and succeed when one is not motivated. Notably, she recognizes how not being motivated negatively impacted her happiness. Yet she still emerged with a positive STEM-related identity intact, if somewhat battered, chalking it up to a "roller coaster ride with science." This is also reflected in her pre-post scores on each of the STEM-related identity scales, which all showed marked declines over the course of the semester.   While certainly not a resounding bolster of her STEM-related identity, did show remarkable self-reflection, grit, and persistence for STEM.

B. SciGirls Role Model Impacts

Kim mentioned that one day Mr. C had brought in a STEM role model to visit the class and share her story -- a woman chemical engineer from. As it turned out, Kim had often babysat for this woman's children but had no previous knowledge of her professional life:

It was really cool because before that I'd only seen her life when she's at her home, which doesn't interact with her profession at all. So it was really cool to see she's got these two lovely kids and her personal life AND this great profession and is able to kind of do it all.

<div align="right">Post-Interview</div>

As a result of the role model visit, Kim imagined herself working at 3M and considered it to be a real possibility. She also had summer plans to attend the Michigan Tech STEM Camp for "Intro to

Engineering," and learned that this role model had gone to this same camp in her youth. Kim's desire to pursue this STEM camp was a result of a different visit from another 3M person who Mr. C. had invited in to talk to the class about the camp and inform them of an available scholarship. Kim applied for and won the scholarship -- joking that now she might HAVE to consider herself a STEM kid.

C. Video Narrative Analysis

Kim's video paralleled her contextualization of her current SciGirls-related STEM learning experiences into a larger narrative. It was arranged chronologically, featuring both older family photos as well as current video from her SciGirls-related chemistry lab. Her theme was 'how she feels about science,' as she related in her director's commentary:

> *I really just wanted to show a glimpse of me and what I felt about science and what I liked about science.*
> Director's commentary

With a simple iMovie music track, she included a contextual set-up, complete with family pictures and a sense of place and history for her position within her family and how that relates to STEM.

> *… I was trying to show what my family was like, what I'd grown up around that led me to really enjoy science. I also wanted to talk about my parents because they are a big reason why I am so invested in science and I succeed today. They are always there supporting me and always ready to partake in science with me.*
> Director's commentary

However, upon switching from the introductory scenes towards a discussion of science (which included her dislike of her chemistry class), her remaining video consisted of only two scenes: (1) Lab sessions depicting typical activities they routinely do, and (2) An action interview with one of her good friends in chemistry lab. For the former, she included a voice over narration recounting her STEM journey through the grades, notably summarizing her experiences thus far in this way:

> *… I think [my STEM classes] have helped me to realize what types of science I'm interested in and what types I would rather stay away from.* Video narration

Her last scene depicting her friend was intended, she said, to convey the idea of how important her friends and her family are in supporting her STEM learning, especially when it is hard to stay motivated.

The scene-by-scene plot map provides an at-a-glance overview of the content and narrative nature of her video (Figure X). It includes a statement of purpose and/or information contained in each scene and was coded according to research model and then color-coded as follows:

1. Self Concept
- **Agency (self-efficacy)**
- **Content confidence (+attitudes)**
- **Role models**
- **Reflected self-appraisals**

2. STEM Concept

3. STEM Commitment

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- **Personal relevance & Emotional connection**
- **Peer influence & Community belongingness**
- **Aspirations**

4. STEM literacy (Capacity to understand and do STEM)

5. Choices (STEM related and peer related)

6. Time spent on STEM (behavioral vs. perceived commitment)

1. Intro sequence I am 15, 2 Sisters, Read, hike, photos, nordic ski. Parents are STEM profs"

2. Personal Science Story Chem lab video Grade-bygrade narrative"
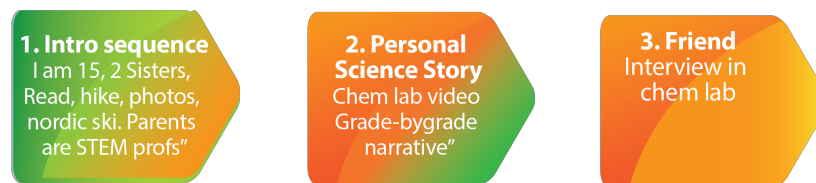
3. Friend Interview in chem lab

Figure 3: Kim's Video Plot Map

Note that her video expressed only two predominant themes (shown in green and orange): (1) self-concept, including agency and STEM confidence, and; (2) STEM commitment, including mostly personal relevance and emotional connection (or lack thereof regarding her chemistry class). She included no details, discussion nor insight that might reveal more about why she disliked chemistry.

As she focused on how she felt about science that year, we see once again how she resolved the conflict of having a negative experience by placing a silver lining at the end -- her good friend and one bright light in the chemistry class, with a voice over about the importance of her friends and family in helping her endure the class. Clearly, she considered her chemistry class more of an ordeal to be managed, rather than an opportunity to advance in STEM. And yet in the end, she demonstrated her persistence and capacity to integrate negative experiences into positive STEM-related identity development.

3. Pre-Post Analysis
As described in the methods, the bounded time for the study was roughly one Spring semester of high school. For each case study participant, this marked the in-class learning experience they had with an educator who had just completed the SciGirls Educator training (described in the appendix). This pre-post analysis examines changes over that time period.

A. Self-Perceptions
Listed here are the pre-post comparisons for Kim's identity sort for the ranking of Importance and Time Spent as Each.

Table 6: Kim's Pre-Post Identity Sort

Importance PRE	Importance POST	Time Spent as Each PRE	Time Spent as Each POST
1. Daughter	1. Daughter	1. Skier	1. Daughter
2. Sister	2. Sister	2. Lover of school	2. Sister
3. Good friend	3. High Schooler	3. Sister	3. High schooler
4. Skier	4. Skiing captain	4. Daughter	4. Skier
5. Upbeat person	5. Skier Reader	5. Good friend	5. Skiing captain
6. Lover of school	6. Reader	6. Upbeat person	6. Life guard
7. Reader	7. Knitter	7. Reader	7. Reader
	8. Lifeguard		8. Knitter

Kim added three identities over the time of the study: she was made "ski captain" shortly after the pre interview (of which she was very proud); she became a "lifeguard" and got a job working at the school's pool (which would extend into the summer); and "knitter." Two identities disappeared from her lists: "Good friend" and "Upbeat person. "Lover of school" was modified into simply, "high schooler," perhaps indicating her struggle to remain a "lover of school" while still acknowledging her student identity status.

B. Role Models

Kim's list of most important role models Pre-Post were as follows:

Table 7: Kim's Role Models

Role Models PRE	Role Models POST
1. Her parents (both college STEM professors)	1. Her Mom (microbiology professor)
2. Ski coach (who is also an astrophysicist)	2. Dad
3. Her older sister (who is in college)	3. Ski Coach
	4. Her older sister

In the post-interview, Kim went deeper into the story of how her Mom inspires her because she took several years off to raise three kids and struggled to get back in the workforce only after the youngest started kindergarten. It was difficult for her mom to find a good job, often getting beat out by younger candidates, but she eventually did. For Kim, her Mom set a powerful example of sacrifice, persistence, and achievement. She also explored her Dad as a role model a bit more, citing that he (like

Kim herself) is a shy person, but inspires her by getting up and teaching in front of a class nevertheless.

Also, she again listed her ski coach, but with the added details that the reason Kim is inspired by her is due in part to her similar struggle to find a job that allowed her to combine her passions for science, skiing, and family -- something Kim stated is an aspiration of hers. Before striking that life balance, her ski coach would spend time away from family in Antarctica to conduct research because "it was really good money," echoing the theme of sacrifice for achievement shown in her Mom as an important role model trait for Kim.

Finally, she again listed her older sister as a role model, who was in college and had recently inspired her by planning to join the National Guard. Although not completely understandable to Kim, she admired her sister simply for "going for it," and being highly driven and motivated.

C. Conceptions of Science or STEM

Notably, Kim's STEM concept was expanded as a result of her chemistry course over the term of the study:

I've always viewed science as the study of living things, especially humans. Of course it's a lot bigger than that. Now especially that I've taken chemistry, it's expanded. ... I kind of view it as like solving a problem that relates to the real world in the sense of something alive in the world. ... Whenever I think of science my first thing I think of is cells and very basic biology stuff. Now it's also balancing equations and all the

chemical reactions that are happening in the world.

Post interview

Not surprisingly (and as reflected in other case studies in the study), sometimes important gains in STEM-literacy and STEM-related identity development occur in spite of a student not liking, or even actively hating, a STEM learning experience. This is not an argument or justification for lack of personal relevancy and engagement in STEM learning, but it is a demonstration (as Kim provides here) that when a student possess of positive STEM-related identity going in, even negative experiences can be framed to contribute to positive STEM-related identity development.

D. Self Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

Kim's self-appraisal as a "STEM person" also changed somewhat over the course of the study. Whereas before she stated that she was a "STEM person" but actually favored reading, she later offered this observation of her changing self-perceptions:

I always considered myself a big English nerd. I read a lot. The more I've done the SciGirls and the more advanced chemistry and biology classes here I've considered myself more STEM-leaning.

Post-Interview

Here Kim refers to having "done the SciGirls." As we see in other cases as well, many of the case study participants regard their weekly gatherings to work on their journals and video narratives as a 'SciGirls

club' of sorts and include that experience in their personal observations and reflection. More on this topic is discussed in the cross-case analysis.

Kim's reflected self-appraisal (whether she thinks others think others as a "STEM person") remained largely unchanged:

I don't think so. One of my good friends, she's really really big into STEM, so me next to her -- I just kinda -- I look more like I'm an English nerd. She's REALLY into science.
                                    Post-Interview

STEM Agency and Self-Efficacy
Kim's perceived ability to understand STEM decreased slightly over the course of the semester, from high to moderate. Her perceived ability to participate in and contribute to STEM activities remained high throughout the semester. Additionally, despite her struggles in chemistry, Kim's academic performance in terms of grades remained high throughout. She maintained straight 'A's.

STEM Commitment
Kim's STEM commitment and emotional connection also remained high over the time of the study. She consistently rated her ability to get excited about STEM as high despite her struggles to stay motivated in chemistry. Her social connection to STEM dropped from 2 close STEM friends to 1. The time she estimated spending on STEM each week dropped from 15 hours to 8 hours, however at the time of the post-interview (near the end of Spring semester) she did indeed have a lighter load for most classes. Finally, Kim's career aspirations changed only slightly:

[My career aspirations are] bio-something. Or an editor of novels. Can I combine this with biology?
                                    Post-Interview

E. Survey Results
A more in-depth discussion of case study participant survey results will be completed when the final overall quantitative study is complete.

Science Identity Scale
Pre: 2.9
Post: 2.4

Girls Interest in Nature and Science Scale
Pre: 3.3
Post: 2.3

STEM Career Interest Survey
Pre: 4.5
Post: 3.9

VNOS: Novice, consistent, no-growth

Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imagination & creativity in their investigations/experiments?

... I feel that most experiments like the ones I do in my science classes are lacking in creativity because they are extremely prescribed. The students don't get to decide what they do at all.
                                    VNOS – Post

4. Discussion
With Kim, we see a girl who enters her sophomore year with a relatively high STEM-related identity despite a mix and positive and negative STEM experiences in her past. It is clear that influencers and role models in her life, including her

parents as STEM professors and others outside of school, had a large impacting helping her maintain this positive STEM-related self-perception in the face of difficulties.

During the course of this study, Kim was experiencing another largely negative STEM learning experience in her class with SciGirls-trained teacher, Mr. C. Her exploration and reflections of this experience within the context of her larger life and her past STEM-related experiences provides us with an important window on how a positive STEM-related identity can bolster a student through hard times in terms of struggle, motivation, persistence.

Notably, Kim had some important gains within her Sci-Girls-related class with Mr. C. Most importantly, this came in the form of the role models Mr. C brought into the class and the big impact they had on Kim's

plans to attend a summer STEM camp (and winning a scholarship to do so) as well as imagining possible STEM-related career pathways for herself through contact with a personally relevant STEM professional from 3M who shard her story in class. Additionally, Kim showed tremendous grit to maintain good grades in the face of her frustrations with her chemistry class and ultimately was able to expand her STEM concept and literacy beyond the realm of biology.

But in the end, despite these gains, we see Kim's STEM-related identity somewhat battered by the end of the semester, with a decrease in most of her STEM-related measures (STEM agency, STEM commitment, and all survey results), while still tenaciously holding onto a positive STEM self-appraisal.

Case Study: Gina

Profile

Gina was a 15 year-old high school student in St. Paul MN at the time of the study. She is the oldest of seven children (five brothers and one sister) and is of Thai descent. She is extremely driven and hard working, spending the bulk of her time on her studies. She is very attentive to her grades and academic performance, making a point to take "the hard classes" despite the stress and time management that comes with her busy schedule.

SciGirls Teacher: Ms. R
Class: Biology

1. Pre-Analysis (Initial Conditions at the start of the study)

A. Self Perceptions

Gina initially described herself as an introverted and quiet person who prefers alone time to social gatherings. As the oldest of seven siblings in a family that immigrated from Thailand in 2003, she thinks of herself as inexperienced and:

… without knowledge in the education system and other stuff such as school or other social activities.

Pre-Interview

When asked to list and rank her perceived identities, here were her responses:

Table 8: Gina's Pre Identity Sort

Importance	Time Spent as Each	Most to Least Pleasing	Ideal World
1. Daughter	1. Daughter	1. Daughter	1. Daughter
2. Oldest	2. Oldest	2. Oldest	2. Challenger
3. K-Pop fan	3. Girl	3. K-Pop fan	3. Risk taker
4. Math club member	4. Introvert	4. Girl	4. Oldest
5. High school student	5. K-Pop fan	5. High school student	5. Girl
6. Sophomore	6. High school student	6. Math club student	6. Math club member
7. Risk taker	7. Math club member	7. Risk taker	7. High school student
8. Challenger	8. Risk taker	8. Challenger	8. Sophomore
9. Girl	9. Challenger	9. Sophomore	9. K-pop fan
10. Introvert	10. Sophomore	10. Introvert	10. Introvert

Notably, Gina listed her two most important identities as those in relation to her family and then shifted (after "K-Pop fan") to her roles at school, with "Math club member" ranked higher than "High school student." This suggests that math has a higher priority for Gina than other subjects, which is supported also supported by other evidence.

She then listed more general identities, "Risk taker" and "Challenger." Gina described her identity as a "Risk taker" as being someone who tries new things she's never done before (like the SciGirls case study participation, she cited as an example). These are things that her friends and most other people do not do, she said. This self-perception becomes important in understanding how she viewed her life and responsibilities, described later on.

Interestingly, her "Girl" identity ranked near the bottom for importance, just above "Introvert," suggesting a minimizing of the importance of her gender identity. And yet "Girl" ranks 4th in her list of her most pleasing identities. Finally, "introvert" is listed last in all the sorting categories except Time spent as each (where it is 4th), suggesting that among all her identities she may not have been entirely comfortable with this particular self-appraisal.

B. Role models:

During the pre-interview, Gina listed her role models. She had only one, her father, whom she admired for his motivation and hard work:

Ever since we came from Thailand he did everything by himself like got a job himself, he actually went back to school by himself,

learned English ... without his motivation he wouldn't even do that.
Pre-Interview

C. Conceptions of Science or STEM

Gina's conception of science was:

The study of nature and how things evolved. Really just the study of how things work. When I'm doing science I'm learning about the natural processes of things by experimenting or doing labs.
Pre-Interview

In this explanation, Gina began with a biological reference to evolution and nature, but then expanded STEM to all things. Importantly, she included the notion of learning through experimentation, a critical component of STEM conceptualization, and indicating more highly developed sense of it.

D. Self-Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

Gina considered unambiguously herself to be "STEM person" and indicated that other people would also consider her to be "STEM person" as well (reflected self-appraisals), including both friends and family.

Within STEM Gina repeatedly expressed an affinity for math in particular. Ironically however, this was reflected in her numerous journal entries describing her anxiety and, at times, low self-efficacy and content confidence for doing math:

Math team to do practice rounds for the purple comet [competition] and I felt so stupid. This is maybe the normal feeling

for me when I go there because people there are so smart. I am the dumbest there. I go there everyday but there is not much improvement because I don't think they know that I don't even understand what concepts they are talking about when they are explaining the problems. The purple comet is in April. I feel like I should just drop out.

Journal

We did permutations and combinations quiz today in math. It's so unfair! There are 5 questions and 50 points are the max amount of score that you can get. I got one wrong and percentage wise it's 80%.

Journal

Statements such as these obviously communicate her great stress around math, but also indirectly demonstrate how much she cared about doing well in Math -- part of taking on the harder challenges above what she believes most others would do.

They also reveal her experience of a great deal of pressure in terms of academic performance, as reflected throughout her journal as she repeatedly discussed the stress of getting schoolwork and homework done (time management), getting good grades, and feelings of uncertainty and academic insecurity.

Yet, Gina rated her abilities to understand and contribute to STEM learning and activities as high. It seemed as though Gina was in a cycle of doubt and uncertainty, driving high levels of effort and time deployment, all governed by her desire to achieve and improve in terms of getting good scores and good grades in school, making a good showing in math club, and perhaps living up to her father's example as a role model.

STEM Commitment

Emotionally, Gina described her relationship to STEM as challenging:

I feel that STEM... it's really challenging cuz most people, and me also, we think that STEM is a thing that you have to work really academically and really challenge yourself in there. Probly people don't want to involve too much time into STEM because they want to do more action or visual things. ... It [STEM] makes me mainly frustrated but I like it. But when there's, like, a bunch of stuff with all of them together, it's frustrating.

Pre-Interview

However, Gina also rated her ability to get excited about STEM as high. Additionally, she spent an estimated 15 hours per week on STEM. Importantly, when asked how many people she would lose contact with if she stopped doing STEM altogether, Gina said 40 to 50. Of those, she considered nine of them to be close friends. This indicates that STEM is a primary pathway for Gina's social connections to other children. Given her highly positive STEM-related identity combined with her introversion, this was perhaps not surprising, but did serve to further increase her connection and commitment to STEM as an important part of her socio-emotional, as well as her intellectual, life.

When asked what career aspirations she might have, she said:

I kind of want to become a bio-psychologist. But it's not a really popular major. ... Because it involves the mental thinking. It's just cool to look at other people [behaving].

Pre-Interview

2. SciGirls-Related Experience
(Experiences during the course of the semester)

A. Reflections

Like all the case studies, Gina's experiences with her particular teacher who was engaged in SciGirls training was blended and contextualized into a larger sphere of life experiences. Gina began the study already considering herself a "STEM person" with an affinity for math. Over the course of the semester, Gina's journal revealed her to be quite driven, self-critical, and somewhat stressed most of the time:

Today is the due date of my MYP project. I am planning on staying up all night to finish my project. I now learn that my procrastination is a horrible thing because now I have a report paper due and also the science worksheet that's due.

Journal

I am so nervous because I did share the document with the teachers but I forgot to share the folder and accidentally sent it when it was 12:00 AM. I was happy that they didn't mind. I felt a weight lifted off my shoulders now. Whewwww!

Journal

I have so many assignments due today! I have an online assignment on hierarchy of service and what a T-Rex tastes like. I don't really mind the T-Rex but for the AP human geo homework, it's the same amount of research as a research paper because it's sometimes really confusing; some things that we had to fill the table in don't even have an answer. Anyways, I'm DONE with it SO YAY ME!

Journal

Today is really stressful! I am really stressed about the presentation test in math and science. I don't know which one I should study first. This unorganized life made me procrastinate more. I got my grip at 8:00 PM and stayed up until 12 to do my studying and practice for tomorrow's presentation.

Journal

An important part of Gina's driving motivation for academic performance was a sense of competition, both with others and herself, to constantly improve that exists both in and out of her school life:

Today is Saturday and the day of my Saturday Academy. I woke up and checked my social media when I realized something BIG. My cousin posted about going on a study abroad trip to Japan. At that moment, I felt idiotic. She is improving her life and experience while I'm sitting here procrastinating about my assignments. Throughout today, I felt totally down because I am not as good as my cousin.

Journal

This kind of self-criticism and self-doubt shadowed much of Gina's reflection during the course of the study. However, she was also capable of positive self-talk and feelings of accomplishment and satisfaction with her performance:

I was lucky that I studied for the quiz because the quiz was an easy A for me! I am soooo proud of myself. But the thing is that there's more assignments coming up that are going to have to be paced by me carefully.

Journal

I am so happy everything is over! Today is my Mom's birthday.

Journal

Her remark about being happy that everything was over is interesting. It demonstrates an attitude of relief at becoming unburdened and un-stressed regarding her STEM learning. Other case study participants framed their STEM-related learning experiences in terms of enjoyment and wonder, while acknowledging some stress as well. Gina took the opposite view of considering STEM a stressor in her life, along with all her other schoolwork. However, her fast-paced, high-stress outlook was not necessarily a negative thing in Gina's perspective. In fact, she reflected on the absence of her hectic activity while on spring break:

> *… I'm enjoying myself but I feel like the days are going by too slow. I thought today was already Friday! The reason may be because I did nothing new over the course of the last few days. This whole time I spent washing dishes, eating and watching drama movies. I felt less anxious of the schoolwork because there wasn't much homework given, so I already finished it on Monday.*
>
> Journal

This love-hate relationship with being incredibly busy and challenged was Gina's normal operating mode. Without it, she felt restless and eager to get back into the daily grind. In this way, Gina's identities as a "Risk taker" and "Challenger" were activated and framed positively by Gina. But she paid a high price in terms of anxiety, lack of sleep, and self-doubt -- all tied in with her STEM-related identity as a student.

In this context, it is interesting that she chose teenage depression as one her school presentation projects:

> *There's this MYP project day where we bring our completed project with an exhibition board and present it to others. When the event started, I saw many other great projects, varying from pottery to sculpture to a robot hand! Mine seems a little lame because I did it on a website. My website was about teenage depression. At first I didn't know what topic I should do, so when the teacher asked, I unknowingly said 'depression' because it is really well know today.*
>
> Journal

Although Gina did not seem to be depressed, it seems she was very aware of how hectic and stressed her school life was and the toll it took on her. This entry stands out as an unusual one compared to the others.

Gina's SciGirls-trained teacher was Ms. R, whom she had for biology. At the start of the semester, she described her in-class learning experience as fun, including a combination of labs, 'cahoots,' assignments, slides shows, and notes.

> *She also does 'first fives' that we do every morning to -- it's kind of sort of like interesting facts or an overview that we might've forgotten or just left out. … [her teaching style] kind of works for me because I have other classes also, so sometimes I just do it so I can get it done instead of looking deeply into it. … I really enjoy it [Ms. R's class] because the room is big and she teaches great, is fun, funny.*
>
> Pre-Interview

Her journal entries regarding Ms. R's biology class focused on the study of Sticklebacks (fish):

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We are now doing an assignment in biology about sticklebacks. I am tired of sticklebacks, but it is interesting and kind of fun to go in depth with a species because we usually just briefly go over a topic with brief examples and then move on. In math we have a unit circle test and I am prepared. I went afterschool to get some help many times before and even today.

Journal

Here we can see Gina commenting on her biology experience, but then quickly turning back to math, which was common throughout her journal entries -- math was never far from her mind. The entry also showed her efforts to go above and beyond for her math studies, as compared to keeping her work in biology to what they do in class or only what was required for the course.

Near the end of the semester, Gina changed the way she described Ms. R's class:

She makes us do examples to get us involved so we can get more into the experiments or more into the topic we are learning. So it's more simple to learn. It's much easier. When I first started I was really confused about all the content because I don't really know much about biology. [Now] I know more about it. We do more labs now and I like to experience it more than just reading it all in books.

Post-Interview

B. SciGirls Role Model Impacts

Gina did not identify any STEM role models that she worked with in Ms. R's class. But she did identify two people who came into class one day to talk about a

marine science program students could apply for.

C. Video Narrative Analysis

Gina's stated video narrative theme was her 'STEM improvement journey.' The subtext of her video was her diligent attention to her scores combined with a hopeful message and firm belief of success through determination and hard work.

The introduction title sequence showed her preparing for a math team competition and included a metaphorical shot of climbing stairs to reach the top (success). She then opened with a shot of getting a bad academic score on one of her trigonometry tests, benchmarking her starting place on this journey. This was followed by time-lapsed scenes of her working hard, studying in different locations, with the message:

I may fail to get good grades now... but if I try my best, studying, and attempting...

Video text narration

And then over a shot of her not-so-great SciGirls-related biology test scores:

...even though I fail at improving, there is always hope in other subjects.

Video text narration

She then declared a philosophical stance in the form of a self-pep-talk:

You don't fail all subjects just because you did bad in one. If you put in more effort in once subject, that subject will always get better results.

Video text narration

To this point, her video narrative was marked by issues of her time spent on

STEM, her level of STEM commitment, her STEM-related choices (choosing to put forth such a high degree of effort), and some elements of STEM agency and literacy.

She then shifted the narrative to explore several obstacles through self-video logs (vlogs). These included: "emotional breakdowns" (where she discussed the stress of her mom's illness); "overlapping projects/tests;" "procrastination;" and "a busy schedule." Each of these obstacles directly or indirectly dealt with Gina's challenge of time management and her STEM commitment. Regarding this sequence, in her director's commentary she explained her reasons for including an exploration of these obstacles, which sheds light on the different life stressors in play on her journey:

[Re emotional breakdown]...of how my mom got sick and how it affected my scores a little bit because I can't go after school and get afterschool tutoring cause my Dad's watching my mom and there's no transportation. The next one [overlapping projects/test] is of me talking about how I have a bunch of tests and I added this to show that it's not just one test that I'm trying to improve, I'm trying to improve on all of my tests, but a lot of tests are going on, so you have to choose a test or project or subject to focus on ... it's creating a conflict between them. And I have six classes and only one study hall so I have to be really precise with my time management.
<p align="right" style="color:magenta">Director's Commentary</p>

Finally, she presented the outro scene -- a shot of scores on paper showing her increasingly better math scores with the message that:

The improvements will be worth it.
<p align="right" style="color:magenta">Video text narration</p>

Math was the subject she put more effort into and thus achieved these results -- a statement of both STEM agency/efficacy and STEM literacy, but not directly related to experiences she has with her SciGirls-trained educator.

The scene-by-scene plot map provides an at-a-glance overview of the content and narrative nature of her video (Figure X). It includes a statement of purpose and/or information contained in each scene and was coded according to research model and then color-coded as follows:

1. Self Concept
- **Agency (self-efficacy)**
- **Content confidence (+attitudes)**
- **Role models**
- **Reflected self-appraisals**

2. STEM Concept

3. STEM Commitment
- **Personal relevance & Emotional connection**
- **Peer influence & Community belongingness**
- **Aspirations**

4. STEM literacy (Capacity to understand and do STEM)

5. Choices (STEM related and peer related)

6. Time spent on STEM (behavioral vs. perceived commitment)

Figure 3: Gina's Video Plot Map

Note that Gina's video expressed three primary themes (shown in orange, brown and pink): (1) STEM commitment; (2) Time spent on STEM, and; (3) STEM-related choices (which correspond to both STEM commitment and time spent on STEM). According to her journal and her interviews, Gina spent the majority of her energy and attention on time management, improving her scores, and a great deal of concern and thinking about the choices around each, so it is not surprising this is reflected in her video as well.

Interestingly, Gina also included two key scenes that communicate STEM agency/self-efficacy and STEM literacy. She presented these as the promise at the end of her journey: (1) Her philosophical beliefs that hard work will pay off in terms of achievement, and; (2) Her parting message of the outro that it (being the hard work and time management challenges) will all be worth it in the end and holding up improved math scores as

evidence of this. This is in line with her journal entries as well, including brief but significant messages of hope and self-encouragement that broke up the otherwise daily stressful juggling act of her journey. So in the end of the video narrative, Gina was vindicated and rewarded for her efforts.

3. Pre-Post Analysis
As described in the methods, the bounded time for the study was roughly one Spring semester of high school. For each case study participant, this marked the in-class learning experience they had with an educator who had just completed the SciGirls Educator training (described in the appendix). This pre-post analysis examines changes over that time period.

A. Self-Perceptions
Listed below are the pre-post comparisons for Gina's identity ranking of Importance and Time Spent as Each.

Table 9: Kim's Pre-Post Identity Sort

Importance PRE	Importance POST	Time Spent as Each PRE	Time Spent as Each POST
1. Daughter	1. Daughter	1. Daughter	1. Daughter
2. Oldest	2. IB person	2. Oldest	2. Teenager
3. K-Pop fan	3. Math team member	3. Girl	3. IB person
4. Math club member	4. Teenager	4. Introvert	4. Math team member
5. High school student	5. Challenger	5. K-Pop fan	5. Sophomore
6. Sophomore	6. Opportunity seeker	6. High school student	6. Challenger
7. Risk taker	7. Sophomore	7. Math club member	7. Opportunity seeker
8. Challenger	8. SciGirls	8. Risk taker	8. Math person
9. Girl	9. NHS member	9. Challenger	9. Researcher
10. Introvert	10. Math person	10. Sophomore	10. SciGirls
	11. Researcher		11. NHS member

Gina had a number of interesting pre-post changes in her identity lists. First, a number of identities dropped from her list. Being the "oldest" of her siblings (the only reference to her siblings in her list) dropped from her list, as did "K-Pop fan."

"High school student" merged with sophomore in the post list and "risk taker" disappeared but "challenger" stayed. Significantly both "girl" and "introvert" dropped from the list, suggesting Gina may have grown less concerned with these identities in the post list. As these both were ranked at the bottom of importance in the prior list, it may be that Gina's newfound validation through several new identities that emerged in the post list pushed these out.

These added identities included becoming an "IB person" (member of the international baccalaureate program), and an "NHS" member (national honor society) -- both quite noteworthy accomplishments for Gina only being a sophomore, and she was clearly proud of them. Gina's math club member identity from the pre list split into two math identities in the post: "Math team member" and "Math person," suggesting a differentiation of her in-class and out-of-class math roles, and perhaps an increase in her commitment to a math identity overall. In any case, it contributed to her STEM-related identity, but was not aligned with her experiences in class with her SciGirls-trained educator.

Gina also added the identity, "Opportunity seeker," which seemed to subsume "Risk taker" from the prior list, as well as "Researcher," which she describes as "if I am confused by something I will go and

50

find and learn all about it" (Post-Interview).

Finally, she added "SciGirls" to her list. As indicated in other case studies, some girls seemed to consider the semi-weekly gatherings of the SciGirls case study participants (to check in and provide time and space to wok on journals and videos) as a component of the program in addition to (or instead of) the SciGirls training their educators received. Gina listing "SciGirls" as an identity here seemed to express affinity to this group of girls, and therefore falls into the category of a social identity. Certainly, given her extensive journal entries and the analysis of her video narrative, it seems these gatherings and her related efforts at collecting, shaping and reflecting on her thoughts and

experiences were important to Gina. It is also possible, however, that she included "SciGirls" in her identity list knowing that the interviewer was a SciGirls researcher and she desired to make a good impression of some kind.

Notably, Gina's most salient identity in importance and time, in both pre and post lists, was consistently that of "Daughter." This fact, coupled with her named role model of her father, helps us to understand why she worked so hard and felt tremendous drive as well as pressure to succeed.

B. Role Models

Gina's list of most important role models Pre-Post indicated no change:

Table 10: Kim's Role Models

Role Models PRE	Role Models POST
1. Her Dad (self-driven, risk-taker, hard worker, achiever)	1. Her Dad

No new role models were added and no change in her father as her one and only role model (or the reasons why he is her role model) were indicated. She admired him for being a highly motivated, hard working, self-made "risk taker" (one of Gina's own initial identities). He was not only an example she aspired to, he was *the* example. In combination with her most salient identity, "Daughter," we see the strong influence of this role model in her life. Additionally, as Gina was the oldest of seven siblings (including 5 brothers), she shouldered a lot of pressure, whether internally and/or externally imposed.

C. Conceptions of Science or STEM

Gina's conception of STEM changed only slightly over the course of the study. Where before she described science as "the study of how things work," at the end of her SciGirls semester she reflected on the ubiquity of science:

[Science is] the explanation for everything -- for everyday everything. To do science means to just live. Because everything you do is science. So if you're living, you're doing science.

Post-Interview

Given that Gina's prior concept of science included both exploring and experimenting, it seems more likely that her later description of science was more of a recognition that science is all around us, rather than a literal belief that anything and everything is science or that science is not in any way different from, say, art, for example.

D. Self Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

Gina's self-appraisal as a "STEM person" remained strong over the course of the study, as did her reflected self-appraisal that she believed others (friends and family) see her as a "STEM person" as well.

STEM Agency and Self-Efficacy

Gina's perceived ability to understand STEM remained quite high during the time of the study, as did her perceived ability to participate in and contribute to STEM activities. Gina's academic performance in terms of grades was variable, of which she was acutely aware and she worked extremely hard to improve her grades (the theme of her video narrative).

STEM Commitment

However, her STEM commitment and emotional connection to STEM remained high during the time of the study, despite this pressure:

STEM is exciting. Especially when there's a new problem for you to solve. Especially in math or science. … I also do experiments at home with food. It doesn't go that well because one, you mess up the dishes and you have to wash and two, there's no food

after you experiment -- most of the time it doesn't go well so it ends up in the trash.
Post-Interview

Her description of experimental home cooking as an example of STEM further indicates her high personal relevancy for STEM, as well as an element of play or doing it for fun beyond learning alone.

As before, for Gina's social connection to STEM, she cited large numbers of students that she knows, and several she considers her close friends, as connected through her STEM classes and math club, reinforcing that STEM was a primary pathway for her social connections.

At the end of her SciGirls semester, when asked what career aspirations she might have, Gina repeated her desire to pursue some kind of psychology or neuroscience. When asked why not math she said:

Math -- it's good when you do it but then when you have to explain it to others and use it to tell other people what you're doing it's not that fun anymore. …I'm not good at explaining stuff to people.
Post-Interview

E. Survey Results

A more in-depth discussion of case study participant survey results will be completed when the final overall quantitative study is complete.

Note: Gina completed the VNOS survey as pre and post but did not complete any other post-surveys for comparisons.

Science Identity Scale
Pre: 1.9

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Girls Interest in Nature and Science Scale
Pre: 3.1

STEM Career Interest Survey
Pre: 3.7

VNOS: Novice, consistent, growth

Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imagination & creativity in their investigations/experiments?

"I think that they use their imagination in all parts of the investigations. Examples would if we were to do an experiment, thinking of what to do requires the person's creativity to think of something. As for experimenting, their creativity also helps them create procedures and directions as to where the experiment is aiming at. And for making observation and analyzing data, if there was no imagination, nothing would be noticed about the data because no thought was put into observing the results of the data. And lastly, for interpretation and reporting results, they both also involves imagination and creativity because if for example we were to do an experiment on baking soda and vinegar, the person could've just said that the baking soda caused the vinegar to bubble up BUT for people with creativity, they would think of the deep reason behind the chemical reactions, not just point it out.

VNOS - Post

4. Discussion

Gina presents an interesting case, combining a well-developed initial positive STEM-related identity with a negative reinforcement mechanism that evidently resulted in improvement and achievement. Gina's tremendous drive to succeed academically was accompanied by tremendous stress (typically about time management and grades) as a normal operating mode that worked for her -- to the extent that grades are a proxy for learning.

However, there are two elements that need to be pointed out. First, Gina's positive STEM-related identity was almost exclusively centered on math. For Gina, it did not even extend to math that was embedded within other subjects, but pure math in the form of math class and math club. Therefore, it would be more accurate to discuss Gina's identity development in terms oh her math identity in particular.

Second, there is very little indication that Gina's STEM-related identity (or math identity) developed at all over the course of the semester. It started high and remained high. Her hard work, determination, and personal sacrifice all paid off in the end as she presented her reward in the form of -- what else -- improved math scores. Her experiences with her SciGirls-trained educator, Ms. R in biology class, had little or no impact on Gina.

However, it is abundantly clear that Gina's work style and work ethic were modeled on her father, further demonstrating the power of role models and influencers on behavior. What remains unclear is whether Gina's perceived responsibility to live up to her father's example was internally by her, or externally regulated by him. Either way, it resulted in the pressure that drove Gina to succeed academically and the accomplishment she felt when vindicated.

Case Study: Sofia

Profile

Sofia was a 16 year-old high school junior in St. Paul MN at the time of the study. She is a middle child with one sister and three brothers. She is of Latinx descent, is very self-aware and introspective. She enjoys being active, doing gymnastics, hiking, and music (she plays the guitar). She also enjoys learning and is a dedicated student, especially in science -- but it wasn't always so. Her love of school and science in particular is a recent development, beginning in her sophomore year and continuing to the present.

SciGirls Teacher: Mr. V.
Class: chemistry accelerated

1. Pre-Analysis (Initial Conditions at the start of the study)

A. Self Perceptions

Sofia initially described herself as a diligent student who cares about her future and tries hard at everything she does. After a meandering middle school experience, including switching into and out of an art school in order to find the "right fit" for her, she described her 10th grade year as the time she really started to apply herself and became interested in STEM. Now in her junior year, she wanted to "double up" on science and was taking both biology and accelerated chemistry because she "wanted a challenge."

When asked to list and rank her perceived identities, here were her responses:

Table 11: Sofia's Pre Identity Sort

Importance	Time Spent as Each	Most to Least Pleasing	Ideal Self
1. Friend	1. Student	1. Lover of people	1. Student, Lover of education, Performer
2. Lover of people (extrovert), Lover of education	2. Friend, Lover of education	2. Friend, Lover of education, Performer	2. Friend, Lover of people
3. Sister, Student, Daughter	3.Sister, Lover of people	3. Student, Lover of music	3. Sister, Lover of music, Daughter
4. Performer (gymnastics, circus, guitar), Lover of music	4.Performer, Lover of music, daughter	4. Sister, Daughter	

For Sofia, STEM was included within her "Lover of education" identity, but was not included as its own separate identity. Also of interest is the number of ties in each of

her initial rank orders, suggesting she perceived a high degree of overlap and synergy among her various identities -- a holistic sense of self.

B. Role models:

During the pre-interview, Sofia listed her role models. There were two:

- Valerie Taylor: A computer scientist and innovative software designer. "She was an advocate for minorities in STEM fields and women," Sofia said.
- Mr. V.: Her SciGirls-trained educator and chemistry teacher.

Importantly, Sofia referenced a recent activity in Mr. V's class in which they made in-class presentations on relatively unknown/unsung scientists, and that is why she found Valerie Taylor.   So, both of her listed role models were STEM-related and one of them gave cause to Sofia's identification of the other as someone she learned to admire and emulate.

C. Conceptions of Science or STEM

Sofia's initial conception of science was provincial in that it referenced what science looked like in school. But notably it also included both different disciplines or areas of science as well as knowledge about ourselves within its grand scope:

...the different disciplines of exploring and learning new things about the world and ourselves. ...Finding out the reasons why things happen. Taking a concept you learn in class and applying it to a lab... and making the connection of the things you learn in lab to real life.

Pre-Interview

D. Self-Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

When asked if she considered herself to be "STEM person," Sofia cringed, citing that her ACT ELA scores were much higher than her STEM scores, but:

I like STEM a lot. I think it's amazing but I'm just not that good at it.

Pre-interview

So her conclusion was that she was not a "STEM person." When asked if others who knew her would consider her to be "STEM person," (reflected self-appraisal) she thought her parents would maybe think of her this way due to their awareness of her affinity to STEM, and also reluctantly concluded that since she recently decided to take two science classes in her junior year that now most of her friends would also recognize her as a STEM person.

Sofia rated her ability to understand STEM as low at the beginning of the study. She rated her ability to contribute to and participate in STEM activities as moderate.

STEM Commitment

Emotionally, Sofia rated her ability to get excited by STEM as extremely high. She described how she really liked STEM but wished she were better at it, particularly math -- which she has struggled with since kindergarten, she said. This presented her with challenges when it came to performing statistics in lab write-ups in biology and chemistry classes.

Perhaps most tellingly regarding her STEM commitment was the fact that she elected to take two science classes in her junior year, including a two-year long IB

biology class, which she brought up more than once and was clearly proud of -- both for taking on the challenge and for performing well academically in the face of the challenge.

Additionally, she spent an estimated 10 hours per week on STEM and identified a social cohort of acquaintances she knew through her STEM of six, but only one considered a close friend. She also expressed an interest in participating in the Science Olympiad (an extracurricular STEM activity) but had not acted on it yet. Her initial career aspirations included vague ideas around physical therapy or biotechnology -- both STEM-related fields.

2. SciGirls-Related Experience
(Experiences during the course of the semester)

A. Reflections
Like all the case studies, Sofia's experiences with her particular teacher who was engaged in SciGirls training was blended and contextualized into a larger sphere of life experiences. At the time the study began, Sofia was fresh from a breakthrough experience in 10th grade biology with a newly acquired love and agency for STEM. This fueled her to pursue STEM above and beyond the required courses to take two electives: IB biology and chemistry accelerated. At the same time, Sofia still thought of herself as a mediocre student, tentative in her STEM confidence, and in need of further validation in order to be confirmed in her STEM choices.

Her journal entries for the semester did not begin until mid-April (halfway through the study period), but clearly reflected this tension between her interest in STEM and

her low sense of STEM agency and confidence, and the recurring theme of low confidence in math:

I'm getting stressed about choosing classes for next year. I wanna take IB physics next year, but I'm scared I won't be able to keep up with the calculus aspect of it. I've always struggled with math and it's extremely difficult to learn it at a fast pace. I would really like to be good at it, but I'm so far behind my peers it doesn't even matter.

Journal

Two of Sofia's identities, "Friend" and "Lover of people," centered around her extroversion, which she explained as her joy to share experiences with others and her need to re-charge by being around friends. This element of her sense-of-self figured into her STEM-related identity as well, as she noted her value of the one close STEM friend she had:

Me and my best friend [Sarah] love science so much. I'm glad I have someone to nerd out about science with. None of my other friends are very interested in STEM.

Journal

This entry shows us multiple aspects of the social component of Sofia's STEM-related identity development. First, it is a strong example of STEM-related peer affinity and influence. This aspect of a close friendship integrated into her STEM experience and overlapping with two of her other identities strengthened both the personal relevance of STEM for Sofia and her STEM commitment.

Additionally, it indicates a highly valued reflected self-appraisal -- what she thinks Sarah thinks of her, and their mutual

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friendship as being able "to nerd out about science" together. Even though it was only one friend, the fact that it was her best friend means that such an appraisal serves as a powerful validation mechanism for her interest in STEM. The fact that they are both in Sofia's SciGirls-related class together was a fortunate circumstance and a reminder of how critical social learning is for STEM-related identity development.

Finally, her entry also reveals that none of Sofia's other friends were interested in STEM, and therefore likely not sharing her excitement for learning STEM. More than a non-validation of Sofia's STEM-related identity, this could be a negative validation for it in the form of perceived pressure *not* to pursue STEM. In Sofia's case however, it seemed only to amplify the importance of her friendship with Sarah.

Sofia's SciGirls-trained teacher was Mr. V., whom she had for chemistry accelerated. She initially described his teaching style as one that used a lot of metaphors and similes to help students understand "structural things." And that he would often go off on tangents, tells stories, talk about "random stuff," and is "really funny." Sofia relayed all this between laughs and brandishing a big smile. She also said that this style worked well for her, noting that Mr. V. moved at a slow pace with a lot of detail:

He makes sure people understand what he talking about, which is something that's nice for me because usually science is, like, hard for me to understand.
Pre-Interview

She remarked on Mr. V's ability to translate complicated ideas to common understanding, thereby increasing their personal relevancy for students:

He makes concepts in chemistry, he just puts in much simpler terms so that it's easier to understand. Like, he compares chemical reactions to, like, a recipe, baking, or whatever. So he just relays complex topics into kind of like everyday things.
Pre-Interview

However, near the end of her semester with Mr. V., she wrote:

I feel like my chemistry class is too easy for me. It's nice that I understand everything and there is no homework, but I don't feel prepared for college chemistry at all. I'm not going to have a clue about what's going on in Organic Chem class in college.
Journal

This entry marked a change from her earlier lower STEM confidence. Also, while the observation is negative, it demonstrates an increased sense of STEM agency, increased STEM personal relevance, and increased STEM commitment for Sofia, as she is talking about definite plans to pursue organic chemistry in college -- an upper level STEM major elective -- an alluding to a high STEM literacy and STEM capacity causing her current chemistry class to be "too easy."

Certainly, all these outcomes are positive for teacher and student alike. However, the concern she expresses indicates that Sofia's prior preference for Mr. V.'s slow-paced and detail oriented approach may have evolved. Alternately, it could also simply indicate a projection of her worries and self-doubt in STEM to an imagined future circumstance in college (e.g. how would she know what good preparation for organic chemistry entails?).

Sofia also later noted that she thought Mr. V. employed more lecture than hands-on instruction:

> *Sometimes we'll do like an occasional experiment or something and I don't really think it helps me that much. Sometimes I kind of just sit and listen.*
>
> Post-Interview

B. SciGirls Role Model Impacts

Sofia identified one "possible" STEM role model brought into the classroom by her SciGirls teacher during the semester. It was a woman recruiting students for a summer engineering program. Otherwise, there were no in-person or video based role models that she could recall, aside from the project earlier in the semester to explore notable but unknown scientists, leading to Sofia's listing of Valerie Taylor as a role model. However, any significant or durable impacts of SciGirls-related role model efforts seem to be non-existent for Sofia.

C. Video Narrative Analysis

Sofia's video narrative was an introspective story of how she came to her love of STEM and what obstacles she faced along the way, so far. Her theme was how STEM is integrated into her life story and who she is.

It opened with montage of Sofia engaged in different activities and interests important in her life (outside of STEM), followed by the set up of her story over a visual sequence of STEM-related shots: students in a plant biology lab; Mr. V. performing a firey chemistry demonstration; jellyfish and seahorses:

> *This may sound odd coming from me, but up until recently I've never really shown much of an interest in science. Throughout all of elementary school and middle school I was under the impression that I just didn't have the right type of brain for STEM subjects. This was mostly caused by my lack of confidence in my academic abilities. Many of my teachers and peers reinforced the idea that you were either good at science and math or you weren't, and I believed for the longest time that I just wasn't good at it and I should not even try to better myself. My self-confidence plummeted even further when sometimes my peers and even my teachers would tease me because I wasn't very good at particular STEM subjects. And what's worst of all is that I believed what my peers said. I believed that I wasn't very smart to begin with and I definitely wasn't very good at math and science.*
>
> Video narration

This set up communicated a more or less typical STEM experience that many students, especially girls, have through the early grades. Notably, it included the unchallenged belief that one is either good at STEM or is not. This 'you either got it or you don't' notion is indicative of a fixed mindset, common to many students' self-perceptions regarding STEM.

Next, Sofia discussed how all that changed during her breakthrough experience, presented over a visual sequence of her and her friend exploring chemistry lab (in her SciGirls-related chemistry class) and shots of a tide pool in biology:

> *But everything changed when I entered tenth grade. I had nervously signed up for an accelerated biology class. I was very very unsure of myself. But as the year progressed I realized that I really enjoyed*

biology and I was actually pretty good at it. I was able to maintain a solid 'A' throughout the entire year. I was always interested in what we were learning and I never wanted to stop. I believe that one of the main reasons I was so successful was because my amazing teacher Mr. K. always believed in me and supported me throughout the entire way. He even encouraged me to double up on science classes the following year.

Video narration

Here we learn that Sofia had a trajectory changing experience, as far as STEM was concerned, and that she attributed it largely to her former biology teacher. We also learn that she perceived her decision to take that biology class as a big emotional and intellectual risk that slowly paid off as she discovered she was good at it. While we don't have many details about what her former teacher actually did, she attributed much of her success to him and his unwavering support, in contrast to all her previous teachers and peers.

In the next segment, over additional shots of her chemistry lab work, Sofia provided an update on her current status after choosing to attend the two classes her former teacher encouraged her to take: chemistry accelerated and IB biology:

I love both of the classes so much and I've learned to appreciate science and what it means to me. For me, science represents overcoming hardships and the barriers you face in your life. With science, I know that I can achieve almost anything.

Video narration

In this excerpt, Sofia tells us she loves both of her current classes, including chemistry accelerated (her SciGirls-related class), in contrast to her other comments about the

class being too easy and inadequate preparation for college chemistry.   This lends some credence to the supposition that her earlier musings were more likely a projection of her concerns and self-doubts for performing well in college than with dissatisfaction with Mr. V's class.

Most notably in this scene, Sofia shared what science means to her. This was more than simply a statement of her science concept or what any expert would say STEM is. Here she was speaking of the symbolic representation of her accomplishments in STEM (something she was told and believed she could never do) as a major component not just of her positive STEM-related identity development, but of her overall identity development as someone who can overcome obstacles and "achieve almost anything."   By this stroke, Sofia invested tremendous personal meaning and commitment in STEM. This seems to be a direct result of her breakthrough 10th grade experience, followed by the continued validation of her STEM-related identity within her SciGirls-related chemistry class and her biology class.

Finally, Sofia's outro discusses her STEM motivation and where it may take her:

I think that a lot of my motivation comes from really comes from really excelling and stepping up in that biology class I had in tenth grade and it gave me the confidence to go on and try much harder things. As of right now, I'm considering possible future careers in biology and other scientific research fields. I definitely wouldn't be where I am now without the support of my teacher from tenth grade and I hope that girls across the world will be able to have the same breakthrough moment that I did.

Video narration

The scene-by-scene plot map provides an at-a-glance overview of the content and narrative nature of her video (Figure X). It includes a statement of purpose and/or information contained in each scene and was coded according to research model and then color-coded as follows:

1. Self Concept
- **Agency (self-efficacy)**
- **Content confidence (+attitudes)**
- **Role models**
- **Reflected self-appraisals**

2. STEM Concept

3. STEM Commitment
- **Personal relevance & Emotional connection**
- **Peer influence & Community belongingness**
- **Aspirations**

4. STEM literacy (Capacity to understand and do STEM)

5. Choices (STEM related and peer related)

6. Time spent on STEM (behavioral vs. perceived commitment)

1. Intro My STEM Story

2. Set Up Low STEM interest & confidence back to elementary

3. Breakthrough Experience 10th gr. bio

4. Current Status 2 classes + science meaning

5. Outro Motivation & the future

Figure 4: Sofia's Video Plot Map

Sofia's video narrative expresses five themes (shown in green, blue, orange, yellow, and pink): (1) Self-concept, including agency and STEM confidence, beginning with her low sense of STEM agency and arcing to a much higher one; (2) STEM concept, briefly appearing as she expressed what STEM means to her personally and symbolically; (3) STEM commitment, recurring throughout most of her video in terms of personal relevance of STEM and the influence of her peers and community - again beginning with negative influences and arcing toward positives ones; (4), STEM literacy as demonstrated near the end as she briefly described her performance in biology, and; (5) STEM choices, showing up in her initial risky choices to take 10th grade biology and later her two STEM courses in

junior year, and then mentioned again at the end when she discusses her STEM future.

In fact, the only coded theme not represented in Sofia's video narrative is 'Time spent on STEM.' However, in her post-interview Sofia did discuss her tight schedule and her competing responsibilities for lacrosse, gymnastics, circus, and schoolwork.

3. Pre-Post Analysis

As described in the methods, the bounded time for the study was roughly one Spring semester of high school. For each case study participant, this marked the in-class learning experience they had with an educator who had just completed the SciGirls Educator training (described in

the appendix). This pre-post analysis examines changes over that time period.

A. Self-Perceptions

Sofia added to her self-description over the course of the study to include "a person who loves putting themselves in new situations," which tracks well with her newly minted pursuit of STEM.

Listed below are the pre-post comparisons for Sofia's identity ranking of Importance and Time Spent as Each.

Table 12: Sofia's Pre-Post Identity Sort

Importance PRE	Importance POST	Time Spent as Each PRE	Time Spent as Each POST
1. Friend	1. Student	1. Student	1. Student
2. Lover of people (extrovert) Lover of education	2. Explorer (of new ideas, theories, and outdoors)	2. Friend, Lover of education	2. Athlete
3.Sister, Student, Daughter	3. "Researcher" (for more school-related activities)	3.Sister, Lover of people	3. Friend
4.Performer (gymnastics, circus, guitar) Lover of music	4. Friend	4.Performer, Lover of music, daughter	4. "Researcher"
	5. Someone who tries to make things fun/enjoyable for everyone		5. Explorer
	6. Someone who tries to help others		6. Someone who tries to help others
	7. Athlete		7. Someone who tries to make things fun/enjoyable for everyone

There are several important changes to Sofia's identity lists. First, she added "Explorer" and "Researcher" and featured them high on her list of importance. She described them both as STEM-related. These replaced "Lover of education" and further specified it. To point out the significance of this delineation, she also added that she had become someone who "hates humanities" including languages, English and history.

Even though I'm better at the humanities, I don't like it. It's so boring for me.

Post-Interview

What's notable about this comment is that her perception of risk for taking STEM at the onset of the study was much higher and her STEM agency and confidence were correspondingly low. As this shifted towards a lower STEM risk perception and greater STEM agency and confidence, her desire to pursue or even enjoy what she had always been good at (the humanities) decreased. So rather than the blanket identity "Lover of education," Sofia became a lover of STEM more specifically. This would also seem to indicate that Sofia embraced a growth mindset in her

approach to learning -- as in, 'don't do what is easy just because it is easy, rather do what is hard and grow from it, if you love it.'

Notably, "Friend" fell from the first rank of importance to the fourth, behind "Student," "Explorer," and "Researcher," further indicating a shift in her priorities. Also, her prior identity, "Lover of people," expanded to both "Someone who tries to make things fun/enjoyable for everyone" and "Someone who tries to help others," which are both related to her "Friend" identity, but indicate a more specific conceptualization of her role as friend. However, "Student" remained at the top of

her time commitment and "Friend" ranked higher for time commitment than both "Explorer" and "Researcher."

"Performer," which earlier included gymnastics and circus, was replaced with "Athlete." "Lover of music" dropped off the lists entirely. And finally, in contrast to her prior identity rankings, there were no ties of any kind in Sofia's final rank orders, indicating a more clearly differentiated perception of her priorities.

B. Role Models
Sofia's list of most important role models Pre-Post were as follows:

Table 13: Sofia's Role Models

Role Models PRE	Role Models POST
1. Valerie Taylor (computer scientist)	1. Mr. K. (10th grade biology teacher)
2. Mr. Karlan (SciGirls-trained chemistry teacher)	

She identified her influential 10th grade biology teacher as her role model in the post interview, Mr. K. Given his prominence in her STEM story, and evident in her video narrative, it is surprising that she did not list him in the pre-interview as well. Both of the role models she did list earlier dropped off her list -- Valerie Taylor because she was more of a timely example given Sofia's recent research project at the time of the pre-interview, and Mr. V., her Scigirls-trained chemistry teacher.

C. Conceptions of Science or STEM

Sofia's conception of STEM changed little over the course of the study. She shortened it to:

The investigation and testing of ideas or theories about the world around you.
Post-Interview

Here she included the idea of experimentation or testing as the link between STEM-related concepts and the real world -- an expansion of her earlier school-based definition. In the following examples, she expanded further on the notion of applying scientific abstractions to real-world problems:

I've been doing, like, for a lot of my IB classes, internal assessments where I have

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to take the concepts we've learned in class and kind of like apply it to real life issues and write a paper about it.
<div align="right">Post-Interview</div>

I'm designing an experiment in biology right now, testing it and doing some data analysis. ... Testing the effectiveness of solar water disinfection. I'm measuring, like, the bacterial growth rates in water before it's exposed the sun and after it's exposed. It's supposed to be lower when it's exposed to the sun. It's used a lot in third world countries to purify the water of bacteria.
<div align="right">Post-Interview</div>

These examples not only demonstrate an important conceptualization of science (experimentation and evidence), but also show Sofia's hands-on experience *doing* science in her classes. Her description of the solar water disinfection study also indicates a degree of her STEM literacy in that context.

D. Self Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

Sofia's self-appraisal as not a "STEM person" changed to a tentative "I guess so" by the conclusion of the study. However, she was again quick to point out that all the other non-STEM subjects came much easier to her, but that although it's harder for her, she finds STEM more interesting. Her reflected self-appraisal, or whether she thinks other think of her as a "STEM person" remained the same -- that most other people she knew would say that she is a "STEM person."

STEM Agency and Self-Efficacy

Sofia's perceived ability to understand STEM increased slightly over the course of the semester, but her perceived ability to participate in and contribute to STEM activities actually fell slightly, indicating a mixed result for her sense of STEM agency, self-efficacy and content confidence.

Sofia's STEM commitment and emotional connection both remained high but qualified:

I have really mixed feelings about STEM. Like, I think it's really frustrating ... but it's also really interesting. [The most challenging part is] the quantitative part. I have a really hard time contemplating numbers and stuff like that.
<div align="right">Post-interview</div>

Here she once again echoed her struggle with math as a component of STEM, but she rated her ability to get excited about STEM learning as consistently high. Additionally, as presented below, Sofia saw extraordinarily large increases in her pre-post scores for every scale. This would seem to indicate that despite her qualifications and apparent frustrations with Mr. V's class, Sofia made great gains in terms of her STEM agency, confidence, and STEM-related identity development.

STEM Commitment

Sofia's commitment to STEM, measured in terms of time, increased from an estimated 10 hours per week to 13 hours per week and she maintained her social cohort of acquaintances associated with STEM at 4 to 6. Finally, her career aspirations were something she said she had increasingly been pondering over the course of the semester. While her initial career aspirations included vague ideas around

physical therapy or biotechnology, she later modified them to include:

...some type of biology research position or something with neuroscience.
Post-Interview

This indicates both more thinking and time spent on imagined future STEM careers as well as greater specificity of what those careers might be. These both indicate positive STEM-related identity development and fall under the categories of personal relevance and STEM-related future choices.

E. Survey Results

A more in-depth discussion of case study participant survey results will be completed when the final overall quantitative study is complete.

Science Identity Scale
Pre: 2.6
Post: 3.0

Girls Interest in Nature and Science Scale
Pre: 2.0
Post: 3.1

STEM Career Interest Survey
Pre: 2.9
Post: 3.6

VNOS: Pre-only: Novice, inconsistent

Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future?

I don't think this knowledge will change but I think that there will be more added to text books as new discoveries are made.

VNOS - Post

4. Discussion

Sofia began the study with hard won positive STEM-related identity, but a fragile one. Having only acquired validation and verification of her STEM-related identity in 10th grade, Sofia was still in a testing mode by her junior year to see if this STEM business would stick for her. To her credit, she took a big risk in signing up for two science classes in the semester and was rewarded when her capacities for learning and doing STEM met and then exceeded her expectations.

At times, it may have been too much of a good thing, however, in that she appears to have become a bit sour on her SciGirls-related class with Mr. V., for it being "too easy," whereas earlier in the semester she was more positive about her chemistry class. Sofia seems to have a pattern of becoming bored by subjects or experiences she finds too easy for her. For example, she observed that she was an excellent humanities student and was better at the humanities than she was at STEM, but that they bored her. Later she reported even hating the humanities. Sofia needs a challenge to keep her motivated, and perhaps even more than that she needs continued validation for her capacity to learn -- either STEM or the humanities.

Interestingly, in Sofia's case, role modeling did not seem to play an important part in her STEM experiences -- either within or without her SciGirls-related classroom. However, the impact of her former 10th grade biology teacher is undeniable as Sofia repeats it at every opportunity. Perhaps he is the source of her affinity for

biology, as this was the first time she had a positive STEM experience in school.

Despite her slight dissatisfaction with her SciGirls-related class, Sofia emerged from the semester having made great gains towards positive STEM-related identity development, evidenced by her increased STEM agency, STEM confidence, and her remarkable gains across all the identity-related surveys. These gains were likely due to a combination of experiences, and perhaps mostly focused on her greater passion for biology (also reflected in her career aspirations).

Perhaps most importantly, Sofia shares with us a view of science as an important symbolic representation of overcoming seemingly impossible obstacles and discovering new potentialities within oneself. In this way and through this perspective, Sofia imparts a degree of personal relevance and investment in STEM that extends into her whole life (even beyond STEM) and is unique in this study.

Case Study: Mindy

Profile

Mindy was a 15 year-old high school sophomore in St. Paul MN at the time of the study.   She is very close with her sister, who is two years older and goes to the same school. Prior to attending high school, she went to a STEM-focused middle school. She is a dedicated and conscientious student. She is of African American descent, is very thoughtful, sincere, and self-aware.

SciGirls Teacher: MS. R
Class: Biology

1. Pre-Analysis (Initial Conditions at the start of the study)

Table 14: Mindy's Pre Identity Sort

Importance	Time Spent as Each	Most to Least Pleasing	Ideal World
1. Sister	1. Girl, African American	1. Sister	1. African American
2. Daughter	2. Student	2. Good friend	2. Girl
3. Student	3. Sister	3. Teenager	3. Teenager
4. Girl	4. Daughter	4. Daughter	4. Sister
5. African American	5. Good friend	5. Girl	5. Daughter
6. Good friend	6. Teenager	6. Student	6. Student
7. Teenager		7. African American	7. Good friend

Mindy's STEM-related identity fell within her "Student" identity, which ranked high for both 'importance' and 'time,' but near the bottom for both 'most pleasing' and for 'ideal world.'   This suggests that she worked hard at being a good student but did not enjoy it as much as her other identities.

A. Self Perceptions

Mindy initially described herself as shy until you get to know her, and then more and more outgoing and funny.   She considered herself to be creative and experimental, enjoying such things as exploring new ways to cook, or putting things together, or playing around with new objects and substances. She did not think of herself as very confident or outgoing.

When asked to list and rank her perceived identities, here were her responses:

Notably, Mindy placed "Sister" at the top of the rankings for both importance and most to least pleasing, indicating the large part her sister plays in her life.   She also delineated both her gender identity as "Girl" and her cultural identity as "African American" as important and most often going together in her different rankings. When asked why she ranked "African

American" last for her 'most to least pleasing' list, she explained:

I think it really influences how other people think of me. I feel like a lot of these [other identities] don't impact as much how people see me and think of, like, how smart I am.

Pre-Interview

However, in the very next sorting to create her ideal ranking of her identities in a perfect world --- her ideal Self -- "African American" jumped to the top of the list, which she explained:

I feel like, kind of like how I said it makes people label me before getting to know me, in an ideal world that would be the opposite.

Pre-Interview

More than the other case study participants, including those of minority ethnic status, Mindy was attentive to and very conscious of the role her blackness played in her life, her sense-of-self, and how others viewed her.

B. Role models:

During the pre-interview, Mindy described her role models in this way:

In general, it's people who have, like, a lot of confidence and determination to go for jobs or fight for things that they think are right even if other people maybe don't agree with them. Because I think that's really important to, like, be able to have the want to do something and then make that thing possible.

Pre-Interview

Mindy was the only one of the case study participants to describe general identity characteristics and traits of the *kind* of

person she thinks of as her role models. Notably, confidence was the first trait she names -- and the one she thought of herself lacking. She struggled to actually name any particular person who served as a personal role model for her. She did mention Katherine Johnson (since she had just seen the movie *Hidden Figures*) as a good example of a person wanting to do something important and not caring so much what others think about it. But she stopped short of saying she considered her to be a role model.

C. Conceptions of Science or STEM

Mindy's initial conception of science was specifically inclusive of the other STEM disciplines:

There are a lot of aspects. When I think of science I think of, like, STEM. So, like, the technology, engineering, and math that also goes into science. A lot of experimenting is usually the first thing that comes to mind but I know it's also like biology and what things are, like, made of, and reactions. I feel like science is, like, a lot.

Pre-Interview

When asked what it means to do science, she included insights into the methods of scientific inquiry and processes:

[Doing science] is a lot of experimenting, creating, like, a research question, a hypothesis, and, like, trying to figure out how something works.

Pre-Interview

Mindy's articulation of both STEM as well as the scientific process itself as involving research questions, hypotheses, and experimentation in order to learn "how something works" is quite advanced. It

indicates as well-structured framework for how science and STEM are related and is unique among the case studies for its clarity in this regard.

D. Self-Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

Mindy initially considered herself to be "STEM person" and cited that she had attended a STEM-focused middle school:

So I feel like a large part of my life has been really focusing in on, like science. I still feel so today.

Pre-Interview

She also referenced the fact that STEM had always been part of home life:

I have always like science. I have many memories of making experiments or engineering things when I was younger. I used to love mixing together random things to try and make something. I would especially love baking. I would mix together random amounts of random things in hopes of making a beautiful cake.

Journal

STEM Agency and Self-Efficacy

Mindy initially rated her ability to understand STEM as high and her abilities to participate and contribute to STEM activities as moderate. She did not, however, think that other people, including friends and family, would describe her as a STEM person (reflected self-appraisals).

STEM Commitment

Emotionally, Mindy described her relationship with STEM as one that could make her happy, under certain conditions:

I like when I'm able to do, like, an experiment or project and it comes out the way I want it to, or it gives me some sort of result. I know that a lot of, like, science and, like, going through experiments and learning stuff is a lot of, like, trial and errors and it gets frustrating when you don't get the answers or the product you want.

Pre Interview

Here she presented an insight into the emotional challenges of scientific investigation that likely only comes from direct first person experience. She remarked how science is different from her experience of math in which there is one certain answer, and with science there is often not. In this way, she said, math is easier.

Mindy did not engage in any STEM activities outside of school and rated her ability to get excited about STEM as low to moderate, with the caveat that:

It takes some time for me to get that understanding, but then once I have a good idea of what we're doing I think it becomes more exciting.

Pre-Interview

Additionally, she spent an estimated 11 hours per week on STEM. Interestingly, she also described her social commitment through STEM as not very strong at her current school and was unable to identify any close friends she knew through STEM, but said she had a cohort of five to ten close friends from her STEM-focused middle school that she was still in contact with, yielding a strong social connection to STEM, but out-of-school.

When asked what career aspirations she might have, Mindy had none as yet.

2. SciGirls-Related Experience
(Experiences during the course of the semester)

A. Reflections

Like all the case studies, Mindy's experiences with her particular teacher who was engaged in SciGirls training was blended and contextualized into a larger sphere of life experiences.

Mindy's SciGirls trained teacher was Ms. R, whom she had for biology. At the start of the semester, she described Ms. R's in-class learning experience as good:
'

She usually will start by explaining the project that we're doing to the class. And then she'll, like, go around to answer questions to make sure that you're really understanding it. She also will stay after school if you need extra time, which I think is a nice thing. Our class is kind of loud sometimes so she has to repeat things a coupe times. She is patient and she is able to take control of the classroom as opposed to letting the students over-talk.

Pre-interview

Mindy indicated that Ms. R's teaching style worked well for her and that she received good grades in the class. She also indicated that she enjoyed the class even when it was difficult, such as when they were studying photosynthesis and cellular respiration. Her enjoyment of the class, she said, emerged when she was able to conceptually piece together the different things they have been learning about, in agreement with her description of how and when she gets excited about STEM.

In her early journal entries, Mindy initially indicated she sometimes struggled to relate her everyday life to STEM. However, within two months of the start of the semester, she remarked:

Science isn't only a subject in school but it is also something I experience in my everyday life.

Journal

As a backbone component to SciGirls educator training, this is precisely the kind of expansive view of STEM we would hope students to acquire. It is evidence of strong personal relevancy of STEM to her broader life. However, Mindy's later journal entries also included important frustrations with Ms. R's class in terms of establishing personal relevancy:

In science recently all we have been learning about is stickleback. Stickleback are the most boring thing ever. I have learned way more than I have ever wanted to learn about these annoying fish. The first couple days I was fine with it, but then we just kept learning about them! My knowledge of stickleback will never be used later in life, I can guarantee it.

Journal

At first glance this may seem like just another instance of the age-old complaint of inexperienced students everywhere, 'when am I ever going to have to know this in real life,' (or some similar formulation). And it is true that young students often cannot discern the importance of the process of learning and learning deeply about something for its cognitive and metacognitive value. As educators are well aware, there can be a nearsighted focus on destinations at the expense of the more valuable journeys among students.

But this observation also underscores the importance of personal relevance in STEM education -- something emphasized in the SciGirls educator training. Here we have a glimpse of what the *absence* of personal relevance can look like. More than just failing to reach students in personally meaningful ways, initial annoyance can evolve into resentment:

The time we spent learning about them we could have been learning about something important like how to prevent global warming.

Journal

These entries date from early March of spring semester. In a follow-up entry from mid-May she says:

We are still learning about stickleback and I'm still not happy about it.

Journal

In Mindy's case, her pre-existing positive STEM-related identity directed her resentment towards wishful thinking of what other STEM-related topics they might've covered instead, which would've been more meaningful to her (global warming). But for students with neutral or negative STEM-related identities, such experiences can simply turn them away from STEM holistically.

By the end of the semester, despite her dislike of the stickleback focus (which she again mentioned in the post-interview), Mindy was able to see beyond it. She reported that and Mr. R's teaching style, including a mixture of presentation, hands-on activities and labs, individual attention, worked well for her. She considered the presentations and note taking at the beginning of new units of

study to be important introductory experiences, but that understanding and excitement did not materialize for her until they worked through hands-on labs.

Finally, in her journal Mindy revealed an important perception about her SciGirls-related experience that was referenced by the other case study participants as well and will be discussed in more detail in the cross-case analysis. This is the 'SciGirls conflation issue,' whereby rather than thinking of this SciGirls project as focused on educator training (which was mostly invisible to these girls), the gathering of the case study participants for weekly meetings to work on their journals and videos afterschool came to be perceived as what SciGirls was all about. It became a "Scigirls club" of sorts, at least for many of the girls. In fact, Mindy refered to it as just that:

Today is the last day of Scigirls. I honestly pretty sad that it's gonna be over. Being a part of this club has been really fun and I'm gonna miss [twin cities public television staffer] and all of the students in the club.

Journal

This reveals two important things. First, that the experience of the SciGirls case study participants was different from that of other students in the classes of SciGirls-trained educators. What those differences are will be discussed later. Secondly, that Mindy and others described inherent value to many of the aspects of belonging to such a 'club' -- or more precisely, participating in the research activities -- such that it may have impacted participant STEM-related perceptions and responses:

My favorite part of this club was getting to meet and talk to everyone in the group every week. A lot of the people in the club I

don't see regularly so it was fun. Throughout the time we have been together, our group has grown and shrunk. … I am happy with the [video narrative], which I ended up doing with my sister. That was a fun way for us to bond over things these last couple months.

Journal

This entry indicates a value for Mindy's personal commitment component to her STEM-related identity through social/emotional ties and a sense of belongingness to a group or community of like-minded members -- in this case the 'SciGirls club,' apart from her experiences in her SciGirls-related class. This social identity for Mindy is then tied to a collective identity for the group, which was shared by other girls to create cohesion and reinforce their STEM-related identities. More discussion on this comes in the cross-case analysis.

B. SciGirls Role Model Impacts

Mindy did not identify any STEM role models that she worked with in Ms. R's class.

C. Video Narrative Analysis

Mindy's video narrative title was "Sisterhood and Science: SciGirls 2017." She created it with her older sister, who was also in the case study cohort for a time. So the video integrated her sister's SciGirls-related experiences, such as in Mr. V's chemistry class lab. However, most of the video focuses on Mindy, as does this analysis.

Mindy's video began with an extended montage of childhood home videos depicting her and her sister engaged in a variety of STEM-related activities. Set over the wistful guitar of Ben Howard's

"Old Pine," with each shot's native sound seeping through, the sequence is both nostalgic and informative. The introduction included scenes of the girls engaged in playground experiments, a centripetal spinning bucket-of-water experiment, and kitchen chemistry. The next segment included a Mentos geyser in the backyard (accompanied by the excited screams of the young sisters), baking science projects, an over-inflating balloon experiment, and a slime-making attempt with a science kit.

Judging by these scenes as well as their number and diversity, Mindy's childhood was steeped in inquisitive STEM-related exploration and play. Additionally, she often shared these experiences with her sister. However over 80% of the five plus minute video narrative focused on Mindy.

The next sequence was a montage of more recent or even current scenes with the sisters, including them working together at home on computers, working together at school on STEM studies, a shot of her sister's SciGirls-trained chemistry teacher diagraming on a smart-board, Mindy meticulously tie-dying a t-shirt in the grass of her backyard, Mindy working with a classmate in a computer lab at school, and her sister engaged in a chemistry lab experiment. All these scenes were presented without commentary or on-screen explanation, but very intentionally chosen and still with the same music over each scene's native sound.

To this point, each scene supported a strong personal relevance signal, showing STEM engagement both at home and in school as a normal part of Mindy's life and that of her family's. The scenes also integrated subtle messages of STEM literacy with hints and snippets of the

STEM content involved in each shot, but the overwhelming theme was emotional connection and personal relevance to STEM.

In the final scene however, there was a shift, as the sisters intercut their personal vlogs (video logs, or self-interviews). Here they shared their reflections from their respective points of view. Mindy's dialogue again raised the "SciGirls club conflation issue," but also contained important information regarding her view of science in her life:

When I first heard about this club, I didn't think that I was qualified because I didn't consider myself to be that involved in science outside of science class. After deciding to join the club, I realized how science is a big part of my life without even realizing it. Me and my sister both live pretty busy lifestyles but one thing we come together for is doing science. After being part of this club I don't think I would be more involved or less involved in science, I just think I'll be more aware of what I'm doing in my everyday life that is considered science.
Video narrative

This dialogue reveals a journey of realization for Mindy, from initially feeling a low sense of agency and confidence for STEM to a revelation that she had in fact been doing STEM all along throughout her childhood. It just never dawned on her that what she considered fun and normal in her life was indeed STEM in disguise. This video and her closing remarks reflected that journey of realization. Beyond her increased sense of STEM agency, this also signals a modification and tremendous expansion of her concept of science in terms of what it looks like in her

life. Mindy touched on this in her director's commentary:

Something else that I was really thinking about and considering when filming and editing this video was a question that [the researcher] asked us in the interview process, which was 'what is science?' And when he asked me that question, even now, I realize that science is such a hard thing to describe because it's in so many different things that it's hard to find one definition.
Director's commentary

How did this journey of realization that she had been engaged in STEM all along come about? Mindy discussed this as well in her director's commentary:

I was inspired to do this video after a week in our club when I was trying to talk to (Twin Cities public Television staffer] about projects I could do. … I told her that I'm not involved in that much science. … I was talking to her about the footage that I did have, which was stuff like me baking, and me in gymnastics, and she brought to my attention that both of those things were scientific. And so I realized that I'm a lot more involved in science than I think I am. So then I was going through old videos and old pictures that me and my sister had -- and we do do a lot of science. It's not something that I was as aware of because it was just fun things that we do together.
Director's commentary

It seems Mindy's breakthrough realization that her life had always been steeped in STEM actually came about due to interactions with a Twin Cities Public Television staffer who was working with her in the context of case study research facilitation.

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A key component of this realization for Mindy was also its linkage to her relationship with her older sister, including the creation of her video narrative, which she described this way:

The thing I enjoyed most about making this video was just being able to look back at all the old videos of me and my sister. … I thought that this project brought us closer together because it gave us a goal that we had to achieve together that we both had to work on, which definitely bonded us. …A question that I considered from my interview with [the researcher] was when he asked us how many people we would lose connection with if we stopped our involvement in STEM. Though I don't think me and my sister would lose connection completely, I do think that we wouldn't be as close because a lot of the things that we do together is … science. … How different our lives would be without that piece.
Director's commentary

Finally, as a self-described introvert, Mindy showed a fair degree of courage with this video and its depiction of highly personal images and thoughts. As she remarked in her journal:

Filming makes me really vulnerable especially knowing other people are going to be seeing what I filmed.
Journal

The scene-by-scene plot map provides an at-a-glance overview of the content and narrative nature of her video (Figure X). It includes a statement of purpose and/or information contained in each scene and was coded according to research model and then color-coded as follows:

1. Self Concept
- **Agency (self-efficacy)**
- **Content confidence (+attitudes)**
- **Role models**
- **Reflected self-appraisals**

2. STEM Concept

3. STEM Commitment
- **Personal relevance & Emotional connection**
- **Peer influence & Community belongingness**
- **Aspirations**

4. STEM literacy (Capacity to understand and do STEM)

5. Choices (STEM related and peer related)

6. Time spent on STEM (behavioral vs. perceived commitment)

Figure 5: Mindy's Video Plot Map

Note that her video expressed four primary themes (shown in orange, yellow, pink, and brown): (1) STEM commitment (mostly through personal relevance); (2) STEM literacy (an inherent part of the many activities depicted); 3) STEM-related choices (including how she and her sister chose to spend their free time and their play); and (4) Time spent on STEM (due to their choices to do STEM as play at home, Mindy spent a large amount of time doing STEM).

The shift towards an exploration of STEM agency and confidence development and STEM concept came at the end with the girls' vlog clips. Here Mindy discussed her sense-of self in terms of STEM capacity and also the realization that STEM is much bigger and broader than she previously thought, given that her home and family life were imbued with STEM learning for many years.

3. Pre-Post Analysis

As described in the methods, the bounded time for the study was roughly one Spring semester of high school. For each case study participant, this marked the in-class learning experience they had with an educator who had just completed the SciGirls Educator training (described in the appendix). This pre-post analysis examines changes over that time period.

A. Self-Perceptions

While Mindy's overall description of herself and her personality traits remained consistent, her identity perceptions had several important changes over the course of the study. Listed below are the pre-post comparisons for Mindy's identity sort for the ranking of Importance and Time Spent as Each.

Table 15: Mindy's Pre-Post Identity Sort

Importance PRE	Importance POST	Time Spent as Each PRE	Time Spent as Each POST
1. Sister	1. Sister	1. Girl, African American	1. Woman
2. Daughter	2. Daughter	2. Student	2. African American
3. Student	3. Friend	3. Sister	3. Student
4. Girl	4. Student	4. Daughter	4. Sister
5. African American	5. Woman	5. Good friend	5. Daughter
6. Good friend	6. African American	6. Teenager	6. Friend
	7. Gymnast		7. Scientist
	8. Scientist		8. Gymnast

Mindy added two new identities to her list: "Gymnast" and, most notably for this study, "Scientist," to be explored further below. Both of these occupied the bottom ranks for both importance and time spent as each. She also modified her earlier identity of "Girl" to become "Woman," an indicator of her maturing into young adulthood and adopting the new identity. Finally, none of her prior identities were dropped from the list, making for one of the most consistent identity lists of the study.

B. Role Models

During the pre-interview, Mindy described her role models in a general way as having a lot of confidence and determination. She only briefly mentioned one potential role model -- Katherine Johnson, featured in the recent film *Hidden Figures*.

At the conclusion of the study, she identified Audrey Lorde as a new role model and the subject of one of Mindy's reports for English class. She was a poet, a feminist, and a civil rights activist who inspired Mindy to become more outspoken and confident in her own world. She also added her parents and her sister to her list.

Table 16: Mindy's Role Models

Role Models PRE	Role Models POST
1. Katherine Johnson (NASA mathematician and space flight expert)	1. Audrey Lorde (feminist, civil rights poet)
	2. Her parents
	3. Her older sister

While somewhat surprising that her parents and her sister did not make her prior list of role models, given how close-knit her family is, she went on to explain that she included them later not simply because they are related to her, but because she looks up to them for being hard workers and exhibiting different qualities she aspires to:

> *My mom is lot more confident in our family. I feel like my dad is really creative and hard working. So is my sister, she's kind of a blend of those two. I would say I'm more like my dad than my mom.*
> Post-Interview

C. Conceptions of Science or STEM

Mindy's conception of science expanded tremendously over the course of the study. As already discussed above, for Mindy science moved out of the classroom only and into her everyday life, where it had actually been all along. Her journey to realize this not only changed her conception of science and STEM, but also her self-perceptions as a STEM person. Where before she described science and STEM as including "a lot of experimenting" and "what things are made of, at the end of her SciGirls semester she attempted again to communicate her much larger vision:

> *Science is everything. It's so hard to come up with a definition because science makes up everything in the world and it explains things that occur in the world.*
> Post-Interview

While greatly expanded, Mindy's conceptualization is also diluted in this formulation. However, it was still being refined and articulated in her mind. When asked what it means to do science, she had

earlier provided a more textbook answer of scientific methods (research question hypothesis, experimentation). In her post-interview, she spoke of the purpose of investigation and used an example from her own personal experience:

> *I think to do science is investigating scientific ideas or theories. Like right now in science we're learning about cells and DNS and RNA. We just finished learning about protein synthesis. So, like, investigating how that works, like how cells and molecules form t make the proteins.*
> Post-Interview

D. Self Perceptions Related to STEM

Self-Appraisals and Reflected Self-Appraisals

Mindy's self-appraisal as a "STEM person" grew over the course of the study, as reflected in her video narrative. While earlier in the semester she had indicated STEM was a part of her home life, the full extent to which STEM was integrated into all aspects of her life this was something she discovered over the course of the study. Asked about the appearance of the new "Scientist" identity to her sense of self, Mindy had this say:

> *Being in the club ['SciGirls club'], I realized I do a lot of science without me realizing because I feel like before I thought that science was just in science class and realize now that, like, I have been doing a lot of science throughout my life and continue doing a lot of it. ... I don't think anything has changed about my lifestyle, I think I've just become more aware of the things I have been doing that involve science.*
> Post-Interview

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This tracks with what she described in her journal and video. When asked directly if this realization had anything to do with what she experienced in Ms. R's SciGirls-related class that semester, Mindy said:

I think it [the realization] mostly had to do with working on the project [SciGirls video project] because I feel like stuff I do in class isn't really something that I would do that much outside of school. ... I came from a STEM focused [middle] school, so I might've been, like, more into STEM inside of school but I feel like now I'm also more into doing STEM outside of school.

Post Interview

Once again there are strong indications that personal relevance is the dominant factor for Mindy's newfound sense that she is a scientist. The interesting nuance here is this notion that if something is only done in school that it somehow doesn't reflect the authentic "you." It's an idea that what occurs in class, stays in class, and is not really part of who one truly is but only what they have to do in school.

For Mindy, the realization that she had been doing STEM at home for years, and that realization leading to her subsequent realization that she is indeed a STEM person -- a scientist even -- is connected to the implicit notion that things that are personally meaningful and part of one's identity are best revealed by what they choose to do with their free-choice time and learning out-of-school (e.g. Mindy's home life activities).

This is an interesting perspective that brings up the issue of "locus of control," referring to how much control a learner has to pursue what they desire vs. control residing primarily with a teacher. When the locus of control resides with the student, personal relevance tends to be higher. When it resides primarily with the teacher, personal relevance to the student depends on the teacher's ability and willingness to explore what interests the students, and tend to be lower -- as can be seen in the earlier example of the tension and resentment surrounding sticklebacks in Ms. R's class.

STEM Agency and Self-Efficacy

Mindy's perceived ability to understand STEM remained high and her perceived ability to participate and contribute to STEM activities increased from moderate to high. Additionally, where earlier she did not think that other people would describe her as a STEM person, in her post-Interview she said:

I don't think it [being a STEM person] would be the first thing that came to their mind when they were describing me, but I think they would agree if I were to say that I was.

Post-Interview

STEM Commitment

Emotionally, Mindy described her relationship with STEM as one that can make her feel curious and have fun and that she enjoyed all aspects of STEM -- science, technology, engineering, and mathematics.

Where earlier Mindy did not identify any participation in out-of-school STEM activities, at the end of the semester she described her other out-of-school activities as now STEM-related, including gymnastics, baking, and engineering projects and crafts at home. Therefore, Mindy's own perception of her STEM commitment was amplified many times.

Mindy also described a large increase in her social connections through STEM, from near zero at her current school at the beginning of the study to include 10 to 20 close friends through STEM by the end (recall she was still in contact with STEM friends from middle school). As well, she referenced her close relationship with her sister through STEM, as discussed in the video narrative analysis above.

However, when asked what career aspirations she might have at the end of the semester, Mindy still had none as yet.

E. Survey Results

A more in-depth discussion of case study participant survey results will be completed when the final overall quantitative study is complete.

Science Identity Scale
Pre: 2.1
Post: 3.0

Girls Interest in Nature and Science Scale
Pre: 2.1
Post: 2.1

STEM Career Interest Survey
Pre: 3.2
Post: 3.5

VNOS: Novice, consistent, no growth

Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future?

I think we will get a better understanding of the scientific ideas and concepts that are already existing. But I don't think any new scientific ideas will be created or

discovered. An example of this is can be the DNA structure. Overtime we were able to figure out more about how the sturucture through the invention of new technology that alllowed us to examine the DNA molecules closer.

VNOS - Post

4. Discussion

Mindy presents us with a fascinating case of tremendous growth in her STEM-related identity over the course of the study, supported by nearly all indicators. Most notably, her self-appraisal included the emergence of the new identity of "scientist" by the end of the semester and it was well integrated with her many other identities to contribute to her larger sense-of-self. Her STEM commitment also increased markedly, as seen through her establishment of more personally relevant connections to STEM, the time she spent on STEM, and the great expansion of her social connections through STEM.

Most of these gains results from Mindy's realization that STEM was, and had long been, embedded in most of her out-of-school experiences, hobbies, play, and family life. Basically Mindy unleashed STEM from the classroom. And in doing so she opened her eyes to an expanded concept of STEM and its place in her life.

Ironically, this change did not occur due to experiences in her SciGirls-related classroom, although there were valuable gains made there. However, Mindy attributed her shift in perspective to interactions with a Twin Cities Public Television employee while working on the creation of her video narrative for SciGirls case study research participation. And so, again we are confronted with the "SciGirls

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conflation issue" of some participants considering their participation on the research to be a designed part of the SciGirls program experience rather than an effort to gain insights into their STEM-related identity linked to their in-class SciGirls experiences. This is discussed further in the cross case analysis.

Although Mindy was hard-pressed to name any significant STEM role models for herself, and her SciGirls teacher did not introduce any that she could recall, Mindy's case clearly demonstrates the impacts of powerful influencers. Mindy's sister was her companion through most of the case study and her co-creator of the video narrative. This relationship was revealed to Mindy to have occurred in the context of STEM from the time they were young girls -- once she recognized the ubiquitous presence of STEM in her life. STEM was and is a very tangible bonding agent for their special relationship.

Finally, Mindy's case presents valuable insight into the importance of personal relevance within the classroom. Although Mindy indicated many gains from her SciGirls-related biology class, and that Ms. R's teaching style and techniques worked well for her, she also developed an annoyance -- and later resentment -- for time and energy spent on a subject she did not view as relevant to her at all. It is tempting to speculate on how Mindy would've viewed her STEM--related identity development for the semester if her story had focused mainly on sticklebacks and did not include her epiphany that STEM was part of the DNA of her normal life and had long been.

Cross-Case Analysis & Discussion

From the review of these six case studies, we have seen that the experiences of these girls as part of the *SciGirls Strategies* program was the result of a vast combination of variables and lived experiences in and around the context of SciGirls. Among these and perhaps dominant were the personal viewpoints, preferences, issues, histories, interests, and interpretations each brought with them by virtue of their incoming identities and pre-existing life circumstances. As revealed in each case, analyzing the impacts and value of the experience for each individual in terms of SciGirls alone or even STEM-related identity alone is not possible. Identity research, by its very nature, invites and welcomes the messy amalgamation of being human. STEM-related identity development cannot, and arguably should not, be separated from holistic life experiences. If we, as educators, teacher trainers, and researchers are to consider STEM learning in terms of identity, we should be prepared to consider a wide range of experiential perspectives, inputs, and outcomes.

With this in mind for the cross case analysis, presented here is an exploration of the notable differences and similarities of the cases, including important emergent themes, in terms of the first two research questions of the study:

1. How does the experience of participating in all of the *SciGirls Strategies* project components impact girls' STEM-related identity construction?
2. What are the impacts of the project's individual components: classroom instruction, role models, and videos and autobiographical story sharing?

1. Cross-Case: STEM-Related Identity Development

Each of the girls in the study entered with an already moderate to high positive STEM-related identity. This is not too surprising given the expected selection bias incurred when recruiting participants to a program called "SciGirls," -- you're going to get girls at least tentatively interested in science, and at most those who are wildly enthusiastic. However there were mixed results in how their initial STEM-related identities fared over the course of the semester-long SciGirls-related experience.

In four out of the six cases, there was strong evidence of positive impacts on STEM-related identity development (Jane, Laura, Sofia, and Mindy). In two of those cases (Jane and Laura), these gains were strongly linked to in-class SciGirls-related experiences. But in the other two cases (Sofia and Mindy), the positive results were not strongly linked to in-class SciGirls-related experiences, if at all. In the case of Mindy, in fact, there is some evidence that her STEM-related identity gains occurred in spite of some negative SciGirls-related experiences.

And for two of the six cases, there were no notably positive STEM-related identity impacts linked to in-class SciGirls experiences. In the case of Gina, whose entire STEM-related identity was based in math, there was relatively little growth in broader STEM-related identity development with no major changes indicated. In the case of Kim, her SciGirls-

related experiences were destructive to her STEM-related identity development and she saw losses in nearly every indicator. However battered, her overall STEM-related identity still managed to survive as positive by the end of the semester.

These results are summarized in the following table along with age and which

SciGirls-trained educator and class they worked with. It should be noted that all the case study participants attended the same school. There were three teachers and two STEM areas represented in the cases, biology and chemistry -- typical sophomore and junior STEM courses.

Table 17: Cross-Case Overview

Name	STEM ID Impact	Age (at start)	SciGirls Teacher	SciGirls Class
Jane	+	15	Ms. R	Chemistry
Laura	+	14	Ms. R	Biology
Kim	-	15	Mr. C	Chemistry
Gina	neutral	15	Ms. R	Biology
Sofia	+	16	Mr. V	Chemistry
Mindy	+	15	Ms. R	Biology

Four of the girls had Ms. R either for biology or chemistry with three of those seeing positive gains in STEM-related identity development, although as pointed out, Mindy's attributed her gains to out-of-class experiences. Gina had a neutral STEM-related identity impact, with no notable gains or losses.

The standout negative STEM-related identity development seen with Kim occurred with Mr. C's chemistry class. According to Kim, this had a lot to do with not liking chemistry, or at least not liking how she was experiencing chemistry in Mr. C's class.

Cross-Case: STEM-Related Identity Components

To help understand these results and compare them across cases, we next explore the components examined of STEM-related identity development. For each participant, these included: self-appraisals, reflected self-appraisals, STEM commitment, and STEM concept.

Table 20 below presents each participant's STEM-related pre-post STEM self concept in terms of self-appraisals and reflected self-appraisal (or what they think others think of them.

Table 18: Cross-Case Pre-Post Self-Concept

	PRE Self-Appraisal "Do you consider yourself a 'STEM person?'"	POST-Self-Appraisal	PRE Reflected Self-Appraisals "Do others consider you a 'STEM person?'"	POST Reflected Self Appraisals
Jane	Kind of	Definitive "Yes"	Kind of	No
Laura	Yes	Yes	Yes	Yes
Kim	Kind of	Yes	No	No
Gina	Yes	Yes	Yes	Yes
Sofia	No	Yes	Yes	Yes
Mindy	Yes	Yes (but much more)	No	Not initially

For most, if they entered with a self-appraisal as having a positive STEM-related identity (being a "STEM person"), they maintained that identity through the course of the study. In three cases their self-concept of being a STEM person was strengthened: Jane, Kim, Mindy. For Kim, this occurred in spite of negative experiences in her SciGirls-related class, but this frustration served to further delineate which STEM subjects she was indeed passionate bout (biology, as it turned out), and thus actually bolstered her STEM self concept in the end. For Sofia, her realization that she could indeed do STEM, after having been told she 'didn't have what it takes' for many years, finally resulted in her embracing a positive STEM self-concept.

The reflected self-appraisals for the cases were interesting. Most tracked with their self-appraisal, however Jane ultimately decided that most others would not consider her to be "STEM person" because of the way she views STEM as to be found within everything and not a specialized or compartmentalized topic. For Mindy, her thought was that others would not initially consider her a "STEM person" until she came out and stated that she was. This was likely because she was still getting to know her newly minted STEM social cohort at her new school.

In the next table we compare each participants pre-post sense of STEM agency and self-efficacy in terms of their perceived ability to understand STEM and to participate or contribute to STEM activities.

Table 19: Cross-Case Understanding & Participation

	PRE Perceived Ability to Understand STEM	POST Perceived Ability to Understand STEM	PRE Perceived Ability to Participate in STEM	POST Perceived Ability to Participate in STEM
Jane	Moderate	High	Moderate	High
Laura	High	High	High	High
Kim	High	Moderate	High	High
Gina	Moderate	High	High	High
Sofia	Low	Moderate	Moderate	Moderate
Mindy	High	High	High	High

Here we can see gains in perceived STEM understanding for Jane Gina, and Sofia. For both Jane and Sofia this tracks with corresponding gains in their STEM self-concepts. Jane also reports a gain in her ability to participate in STEM - the only gain in this category.

However we see a decline in perceived understanding for Kim. This tracks to her feelings of being lost and unmotivated in Mr. C's chemistry class.

Sofia's initial low perceived understanding of STEM is interesting given her feelings of being a "STEM person" at the outset and having attended a STEM middle school. Judging from her perceptions of STEM, it is possible her awareness of how large and complex STEM can be contributed to her feeling that she has a lot yet to learn -- an attitude not reflected as much in the other cases.

In the table below we compare pre-post STEM commitment across participants in terms of emotional connection to STEM, social connection to STEM (number of close STEM friends), and time spent doing STEM.

Table 20: Cross-Case STEM Commitment

	PRE "How do you feel emotionally about STEM?"	POST "How do you feel emotionally about STEM?"	PRE Number of STEM Friends	POST Number of STEM Friends	PRE Hours per week on STEM	POST Hours per week on STEM
Jane	Variable (confused, excited, nothing)	Important, interested, curious	1	1	15	8-10
Laura	Excited	Excited and proud	5-6	5-6	17	35
Kim	Strong, excited	"Still excited"	2	1	15	8

Gina	Excited	Excited, committed	40	40	20	20
Sofia	Nervous, excited	Happy, excited	4	6	10	13
Mindy	Curious, fun, happy	Part of my life	0 (in her school)	10-20 (in her school)	15	3

Emotionally, there were positive gains across all cases in terms the girls establishing stronger connections to STEM with the exception of Kim, who was fighting all semester to maintain her positive STEM-related identity. For social connections, we see gains in the number of close STEM friends for Sofia and Mindy, while Laura and Gina stayed the same. It is worth noting that Gina's primary social outlet was STEM -- mostly from her participation in math club. Her high reported numbers of STEM friends included people she knew through club competitions and not all were close friends. Only Kim saw a decrease in her social connection to STEM, corresponding to her feelings of isolation and un-motivation for chemistry. Finally, there are some perhaps surprising drops in time spent on STEM even for those participants

showing growth in STEM-related identity development. Note that the final interviews took place at different times near the end of the semester and in some cases workload had significantly declined as summer approached, skewing results. However, notably, Laura greatly increased her time spent on STEM through reading and researching at home in preparation for her GLA trip to the Galapagos and other interests.

Finally, we look at pre-post changes in STEM concept across participants as an indicator of strengthening STEM-related identity. In most cases, participants described their concept of science, but some broadened it to include all of STEM.

Table 21: Cross-Case Pre-Post STEM Concept

	PRE STEM or Science Concept	POST STEM or Science Concept
Jane	The study of the world through experiments and modeled analysis.	Same - greater emphasis on experimentation as way to learn
Laura	*[Science is] the exploration of what we don't know to find out what we do.* *I believe its nothing really definite. That's what my 8th grade science teacher told me -- that there's a whole recycle of information. Sometime ago everyone was convinced the truth is the world was flat and now it's that it's round. And what people believe now probly will be disproven in the future and that will be disproven again and it's just trying to figure out what's going on.*	*I would define science as a study of unexplained things to try and get a greater understanding by finding the most logical conclusion based on evidence.*
Kim	*Science is study of living things. It's more expansive than that, but I always think of biology when I think of science.*	*I've always viewed science as the study of living things, especially humans. Of course it's a lot bigger than that. Now especially that I've taken*

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		chemistry, it's expanded. ... I kind of view it as like solving a problem that relates to the real world in the sense of something alive in the world. ... Whenever I think of science my first thing I think of is cells and very basic biology stuff. Now it's also balancing equations and all the chemical reactions that are happening in the world.
Gina	*The study of nature and how things evolved. Really just the study of how things work. When I'm doing science I'm learning about the natural processes of things by experimenting or doing labs.* Pre-Interview	*[Science is] the explanation for everything -- for everyday everything. To do science means to just live. Because everything you do is science. So if you're living, you're doing science.*
Sofia	*...the different disciplines of exploring and learning new things about the world and ourselves. ...Finding out the reasons why things happen. Taking a concept you learn in class and applying it to a lab... and making the connection of the things you learn in lab to real life.*	*The investigation and testing of ideas or theories about the world around you.* *For me, science represents overcoming hardships and the barriers you face in your life. With science, I know that I can achieve almost anything.*
Mindy	*There are a lot of aspects. When I think of science I think of, like, STEM. So, like, the technology, engineering, and math that also goes into science. A lot of experimenting is usually the first thing that comes to mind but I know it's also like biology and what things are, like, made of, and reactions. I feel like science is, like, a lot.* *[Doing science] is a lot of experimenting, creating, like, a research question, a hypothesis, and, like, trying to figure out how something works*	*Science is everything. It's so hard to come up with a definition because science makes up everything in the world and it explains things that occur in the world.*

It is encouraging to note that across all cases, each indicates their perception of STEM or science as a pursuit of knowledge, rather than a pile of facts. But in general, there is no deeper awareness reported about how science, as a collective endeavor, actually goes about investigating and exploring the world through a scientific process.

The exception is Mindy's PRE response, which also includes the other STEM subjects, as well as research questions, hypotheses, and experimentation. It is interesting to note that Mindy's POST conceptualization of STEM is based on her greatly expanded perception of STEM in her life. While her Pre response is almost textbook, her post response reflects her struggle to redefine STEM in the face of its expansion in her mind.

In fact, across three cases, there is a trend of expansion of STEM concept. For Kim (who gained this from the chemistry class she disliked), Gina, and Mindy there was a realization over the course of the semester that STEM was all around them everyday. But it was only for Mindy that opening her eyes to the presence of STEM in her life outside of school and in her home, resulted

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in her declaring "scientist" to be one of her new identities.

Also notable is that for Sofia, uniquely, STEM took on a personal meaning over the course of the study to become a symbolic representation for overcoming obstacles in one's life. This was due to her newfound STEM success after years of being discouraged and teased by peers and teachers, as she described in her video narrative.

How important is STEM or science concept accuracy to the development of positive STEM-related identity? A few notes of perspective to address this question clarify why this is included in the analysis. In contrast to STEM or science literacy, which refers to a person's capacity to understand and interpret STEM-related efforts, findings and conclusions, STEM-related identity (like all identities) refers explicitly to an internally held idea about oneself. Therefore, while STEM literacy must be based on an externally described body of knowledge and skills, a person's STEM-related identity's reference is inward towards a STEM self-concept. This STEM self-concept is generated, in part, from the growing congruency between one's perceptions of her individually held STEM-related identity standard (what a "STEM person" is or ought to be), and an internally held personal identity related to STEM (what being a "STEM person" means to me). This clearly implies that as one's perceptions of a STEM-related identity standard grows and becomes more sophisticated, along with an improving concept of STEM or science, so too will the sophistication of one's own personal STEM-related identity.

For example, we might not consider a 10th grader to be extremely STEM literate, but we might very well perceive the same 10th grader to possess a positive STEM-related identity in reference to what she perceives STEM to be, including who "STEM people" are and what they do. For each of us, as our understanding of STEM grows, so too does our understanding of ourselves in relation to it. That is why the growth of STEM concept is a critical component of STEM-related identity development. In the context of this cross-case analysis, we view the girls' STEM concept and linked STEM-related identity as an important precursor to STEM literacy and pro-STEM choices.

Finally, in considering the STEM-related identity impacts in relation to the participants' many other identities, we need to examine their pre-post identity card sort responses, indicating any changes in their composition and hierarchies. Since the most salient impacts were revealed in the "importance" and "time" rankings, these are the ones included in each case study pre-post analysis section. The combined results in table format are too long to be presented together here, but some observations are warranted.

For all the girls, "STEM" or "science" was not explicitly part of any identities in their lists -- at least at first. However, in all cases the participants stated that STEM was embedded within their identity of "student," which each listed in some form. This simple fact disguises an important observation -- that in these girls' perceptions, STEM or science is something that resides at school and is accessible to them only through their role as a student at school. That is, they access STEM only through their identity as students. Their personal relevancy for STEM comes through their role as students before any other identity. And yet, we have several

examples of participants expanding their conceptualization of STEM to reach beyond school by the end of the semester.

Only in Mindy's case, did "scientist" appear on her post list of most important identities as a result of her conceptual expansion of STEM. Why? What made Mindy different?

The evidence in hand suggests that Mindy established a greater degree of personal relevance to STEM along with her expansion of STEM concept. Her expansion involved the realization that STEM was embedded throughout her life and always had been, both through her experience at a STEM middle school and through her home and family life. Perhaps most important of all for Mindy was her close relationship with her older sister -- a relationship, she observed, that was based on and reinforced by STEM learning and STEM play. This element of personal relevance is discussed in more detail below among the emergent themes across the cases.

Another notable observation was revealed by the identity list and rank exercise having to do with agency transfer. As explored in Laura's case study, by the end of the semester she had acquired a much greater degree of confidence in her volleyball playing and leadership abilities. This was due to events in recent tournament play. She went on to explain that this newfound confidence had allowed her to not get so anxious about performing poorly on a STEM test, and even to approach STEM with the same kind of confidence she had demonstrated on the volleyball court. At the time of the final interview, she was considering doubling up on science courses for her next year in school. Laura dubbed it a "confidence snowball" (getting bigger as it rolled). From an identity theory perspective it is a powerful example of harmonious identity overlap (as opposed to identity conflict) that featured agency transfer from one identity to another; from her athlete identity to her STEM-related identity, in this case. It also demonstrated a greater willingness to take risks (discussed more below) and suggested a growth mindset approach to STEM learning as well as to sports.

Again we can ask why only Laura? But in fact Laura's example of identity overlap was just the most salient. The other participants also demonstrated identity intersections, such as Mindy's observations of her ethnic identity as an African American affecting her identity as a student. And Kim's struggle within her student identity to both love biology and hate chemistry and still maintain her positive STEM-related identity in between. And Gina's intense struggle for effective time management between her identities as student, daughter, sister, friend, and more.

A closing thought about the identity list and rank exercise that was part of the identity interview -- and what we may learn from it...

There are some limitations to this research technique. At best, it gives a snap shot of the participants' sense of identities at a particular time. Obviously there is considerable flux and flow depending on what is on the person's mind when asked. For example, when "Music lover" or "Explorer" drops off of a list, it does not necessarily mean those identities are gone; they are simply not in mind at the time of the query. Therefore, one should not read too much into the results.

However, in concert with other data such as indicators of commitment to identities and of growth in agency, we can make some informed observations.

2. Cross-Case: Video Narrative Analysis

The video narratives created by the participants represented personal introspection and the establishment of personal relevance to STEM-related experiences both related to and independent from their SciGirls-trained teachers, although the nature of these links differed for each person. The video narratives represented the final culmination of the participants' meaning making and reflections for this study. As such, they also provided a valuable data source for the study and the interpretation of their experiences, and in some cases for their own interpretation of their experiences as well.

Table 16 presents each participant's video theme, the researcher-designated narrative type or category of their story, and the coded themes present for STEM-related identity development.

Table 24: Cross-Case Video Narratives

Participant	Theme or Title	Narrative Category	Identity Themes
Jane	STEM is all around us everyday. Title: "The S.T.E.M. and I: An Experimental Process."	Education (learning, changing, growing): Revealing STEM in everyday life to enrich both	(1) Self-concept, including agency and STEM confidence; (2) STEM commitment, personal relevance and emotional connection; (3) STEM concept; (4) STEM literacy as demonstrated in her bread baking tutorial sequence.
Laura	Unification of her love for nature and conservation with STEM learning.	Maturation (coming of age)/ Education (learning, changing, growing)	(1) Self-concept, agency and STEM confidence; (2) STEM commitment, personal relevance and emotional connection; (3) STEM concept, and; (4) STEM-related choices
Kim	How she feels about science. Title: "[name]: SciGirls Video"	Maturation (coming of age)/ Education (learning, changing, growing)/ Testing (will power, facing challenges)	(1) Self-concept, including agency and STEM confidence; (2) STEM commitment, mostly personal relevance and emotional connection (lack thereof regarding her chemistry class).
Gina	Her personal STEM improvement journey.	Testing (will power, facing challenges)/ Redemption (Rebirth, vindication): Through her diligent attention to scores	(1) STEM commitment; (2) Time spent on STEM; (3) STEM-related choices (STEM

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		and belief of success through determination and hard work.	commitment and time spent on STEM).
Sofia	Her story of SEM becoming important in her life. Title: "SciGirls Video Project by [name]"	Maturation (coming of age/ Education (learning, changing, growing)	(1) Self-concept, agency, STEM confidence, beginning with her low STEM agency and arcing to higher one; (2) STEM concept, symbolic representation; (3) STEM commitment, personal relevance, influence of peers and community (negative arcing to positive; (4), STEM literacy; (5) STEM choices, (initial risky choices to take 10th grade biology, later her two STEM courses
Mindy	STEM is part of me and my family Title: "Sisterhood and Science: SciGirls 2017."	Maturation (coming of age)/ Love (sister, family, STEM)	(1) STEM commitment, personal relevance; (2) STEM literacy; (3) STEM-related choices (how she and her sister chose to spend their free time); (4) Time spent on STEM

The narrative categorizations are presented to aid in comprehending the meaning of the video narratives – both for those who made them and those audiences for whom they were made. For it is certainly true that storytelling requires (1) the narrative, (2) the teller, and (3) the hearer. They are based on acclaimed writer Robert McKee's landmark book, *Story* (1997).

Narrative typology

- Adventure (quest)
- Maturation (coming of age)
- Education (learning, changing, growing)
- Testing (will power, temptation, facing tragedy, death)
- Love (romance, family, other)
- Redemption (rebirth, - to +)
- Punitive (+ to - with punishment)
- Disillusionment (worldview changes from + to -)
- Loss

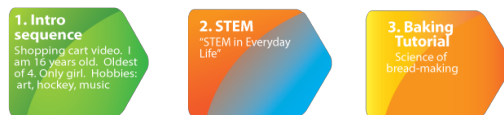McKee, (1997)

All of the videos were first order narratives. That is, they were first person stories about the participant's own experiences, as each was asked to produce. The formats, content, styles, and themes were all free choice and unlimited. The

STEM-related identity themes are based on conceptual framework for the research as conducted in the analysis of each case. Below are also depicted each of the video plot maps assembled together, revealing these themes in color code for easier comparison.

1. Intro sequence
Shopping cart video. I am 16 years old. Oldest of 4. Only girl. Hobbies: art, hockey, music

2. STEM
"STEM in Everyday Life"

3. Baking Tutorial
Science of bread-making

Jane's Video Plot Map

1. Intro sequence
Who she is. "Part of me is in love with STEM"

2. Montage of Her World
Integration of family, friends, adventures, and learning

3. STEM merges w/ conversation
Constant questioning "Why?"

4. Outro
Reflections on STEM, challenges, gratitude, and future-looking

Laura's Video Plot Map

1. Intro sequence
I am 15, 2 Sisters, Read, hike, photos, nordic ski. Parents are STEM profs"

2. Personal Science Story
Chem lab video Grade-bygrade narrative"

3. Friend
Interview in chem lab

Kim's Video Plot Map

1. Intro:
Doing math on board / climbing stairway "My journey of striving for improvement

2. Working:
Pen & paper Audio: clock ticking

3. Working:
Studying in library

4. Working:
Computer at home

5. Biology Scores:
Failing to improve

6. Philosophical Statements

7. Obstacle Vlog:
Emotional breakdowns

8. Obstacle Vlog:
Overlapping projects/test

9. Obstacle Vlog:
Procrastination

10. Obstacle Vlog:
Busy schedule

11. Outro:
Math scores improving

Gina's Video Plot Map

1. Intro
My STEM Story

2. Set Up
Low STEM interest & confidence back to elementary

3. Breakthrough Experience
10th gr. bio

4. Current Status
2 classes + science meaning

5. Outro
Motivation & the future

Sofia's Video Plot Map

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Mindy's Video Plot Map

Note that STEM commitment (orange) is one of only two STEM-related identity themes appearing in all videos. This mostly included personal relevancy of STEM to the girl's lives. STEM agency, efficacy and confidence (green) is the other STEM-related identity theme appearing in each video, but it is less prominent. These two themes typically occurred together, with the exception of Mindy's video, where her sense of STEM agency is dealt with only briefly at the very end. Overall this suggests that when asked to create these autobiographical narratives, personal relevance and STEM agency (whether high or low or both) were the dominant themes important to their development of STEM-related identity. In line with this, we see the most common narrative category is maturation often coupled with education, suggesting that STEM was perceived as integrated into the girls' growing up stories, part of who they are becoming along with other lived experiences.

This kind of identity integration is an encouraging sign for the development of positive STEM-related identity, especially when we see the effects of it unfolding within the course of the semester. This was most salient with Mindy, where STEM was initially boxed to exist only within school, and then we see a revelation occurring when it is let out of that box. This expansion of STEM into the girl's broader lives is a theme also occurring for Jane, Laura, and Sofia. This is of course, amplification of the personal relevance of STEM.

An important question amidst these observations is whether or not we see any indications of SciGirls-related classes in these videos. The answer is yes, tracking with what was observed from other data sources. Jane, Laura and Sofia explicitly call out their Scigirls-related experiences as positive influences in shaping their video narratives (whether in the videos themselves or their Director's Commentaries). And in Kim's video she presents her struggle with her SciGirls-related class (Chemistry) as a negative influence, but one that she attempts to put a silver lining on, as in 'I learned what kinds of STEM I don't like.' Gina's and Mindy's videos do not touch on their SciGirls-related classes, but do include their SciGirls case study gatherings as notable influences.

3. Cross-Case: Emergent Themes

Here we explore what seemed to be the most significant emergent themes in terms of impacting the girls and/or informing us about the their STEM-related identity development.

Role Models

Across the cases, the girls had difficulty naming role models. The exception to this was Laura, who came ready with her pre-established "hero list" and had clearly done deep reflection on the topic. But for the others, the question of "who are your most important role models?" was met with a widening of the eyes or a cringe and almost always a long pause. Note that this question was open to any and all role models for any and all reasons, not restricted to STEM or role models introduced by their teachers in the context of SciGirls or classroom instruction. For most, it appeared they had never thought of or been asked about their role models before, indicating they don't often think in terms of "role models" or role modeling. Perhaps not many people do. Perhaps whom our role models are and what impact they have on our lives is much more unconscious than conscious.

This lack of recalled role models persisted even after prompting for in-person role models, online role models, and/or video-based role models. Only one of the girls listed any STEM role models brought into class by their SciGirls-trained teachers, and this was Kim's experience with a woman chemical engineer from 3M who visited Mr. C's class, and whom Kim also happened to babysit for. In this instance however, it was clear that even the single exposure to this explicit role model was important for Kim's STEM-related identity development – thus apparently

corroborating the findings regarding role modeling in the quantitative part of the study.

Overall, however this lack of clarity in general regarding role models is important and supports two conclusions: (1) The SciGirls-trained teachers of these participants were not very successful in engaging role models, and/or; (2) The girls were not recalling or recognizing "role models" as such.

For example, Sofia did mention a project in Mr. V's class about researching unsung scientists and learning their stories, which resulted in Sofia naming computer scientist and social activist Valerie Taylor as an initial role model, but she later indicated that was only because Taylor was top-of-mind at the time of the pre interview, rather than a durable source of inspiration in the way role models are commonly thought of.

However, in the context of other queries and reflections (such as the identity interviews for example), the girls began to reveal what may be called "influencers" in their lives. These were people such as siblings, coaches, current and former teachers, and parents who were not recognized by the girls as "role models" but did have significant power in the girls' lives and on their self-perceptions and/or aspirations. In most cases, these influencers were not celebrities or well-known people, except for Jane's listing of actors Lisa Kudrow and Robert Downey Jr. and Mindy's listing of NASA scientist Katherine Johnson of *Hidden Figures* fame. Rather, most were people who had high personal relevance to the girls. In some cases we would consider them "near-peer" role models, such as Sofia's mysterious #11 on the opposing team, whom she admired for her grit and tenacity.

Certainly, the greater the personal relevance of the role model to the girls, the more influence they had.

In one case, Mindy preferred to list characteristics she admired and aspired towards in others, rather than citing actual people she considered to be her role models. That is, she was modeling on traits rather than people to define the kind of role -- the kind of person -- she wanted to be.

As an emergent theme, these results give rise to the need to recognize and articulate different kinds of role models as important to programs such as SciGirls, which seek to advance role modeling as a pathway to broadening participation in STEM for non-majority group students. Viewed through a social identity theory lens, we recognize three primary levels of identity: Role identities, defined by the societal positions and functions we occupy; Social identity, defined by group affinities and associations by which we belong to a community or communities in our lives, and; Personal identity, defined by unique aspects of ourselves that set us apart from and/or connect us to others (Burke & Stets, 2009). Together these nested identities comprise our self-concepts. Based on this framework and the findings, it is necessary to unpack the monolithic concept of 'role model' to differentiate role, social, and personal influencers who exhibit traits and behaviors that inform these levels of identity.

In this way, we may find and structure important distinctions between teachers, mentors and sponsors, or important peers or near-peers, for example, such as we saw with Kim who struggled between her parents' STEM encouragement, her discord with her chemistry teacher and class, and the promise of an example

success story in the form of a 3M engineer visiting her class. There is also evidence for important differences in types of influencers such as aspirational vs. inspirational vs. validational vs. even antagonistic influencers.

Finally, this cross-case analysis also reveals that many of the important influencers for these girls embodied a work-life balance between their STEM engagement and "having a life" as well. This seemed to appeal to most of the girls, who were also struggling to find this balance for themselves -- and see their way to a future where they could achieve satisfaction through harmonious identity overlap and intersection. It seems that the more inclusive a STEM-related identity becomes, the more STEM commitment and integration of STEM into their lives and sense-of-self. Successful role models, or influencer, can point the way.

SciGirls Conflation Issue

In many of the cases, there were indications of a 'SciGirls conflation issue,' whereby rather than thinking of this SciGirls project as focused on educator training (which was mostly invisible to these girls), the gathering of the case study participants for weekly meetings to work on their journals and videos afterschool came to be perceived as what SciGirls was all about. It became a "Scigirls club" of sorts.

This is a not an uncommon issue for such research participants in that the additional required reflection, articulation, and communication (interviews, journals, videos), as well as the relationships they develop with peers or program facilitators becomes part of, and can deepen, the nature of the experiences under

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investigation. This is sometime referred to as the "observer effect," or the "Hawthorne effect," in which participants modify their behaviors as a result of being aware that they are being observed. However, in the case of participatory research design, the research participant *IS* one of the observers, as they are called upon to introspect and then communicate that introspection in various ways. Notably, while it seems the effect was universally positive in this study, it can also happen that such observer effects and/or research staff interactions can spoil experiences if implemented poorly.

So what does this mean for SciGirls? As briefly discussed above, it revealed two important things. First, that the experience of the SciGirls case study participants was different from that of other students in the classes of SciGirls-trained educators. The act of participation in this research did not simply reveal cognitive and non-cognitive processes and events of interest for the study, but in many instances it helped to create and define such processes and events.

Secondly, girls described inherent value to belonging to such a 'club' -- or more precisely, participating in the research activities -- such that it seems to have positively impacted participant STEM-related perceptions and responses by providing a sense of community and belongingness not present or perhaps not possible in their SciGirls-related classes. Such a sense of belongingness served to promote STEM commitment and personal relevancy by reinforcing a social identity as a group member -- something others in the classes would not necessarily experience to the same extent.

As we have seen with several of the observations regarding this 'SciGirls club,' the girls valued the experience of being part of it. In Mindy's case, she even attributed her personal revelation of STEM infused in her life to her video narrative work and the interaction she had with a program team member in creating it. So certainly, there is a positive skewing of some of the perceptions of the case study girls. However, the results also indicate a clear delineation between impacts of this group and impacts related to their SciGirls-trained teachers.

Further, the potential observer effect is also one of the rationales for conducting a mixed-methods study that includes control and experimental group survey results. The results of the case study are meant to enrich our understanding of what may be behind the numbers and the impact of SciGirls teacher training on students, but also to put the case study results into the context of the larger study results. In this way, we do indeed draw insights into *how* positive STEM-related identity development actually occurs, beyond whether or not it simply did occur.

Most emphatically here, the ScigGirls conflation issue strongly reveals the importance of personal relevancy as a dominant, of not THE dominant factor in STEM-related identity development for these girls. Which brings us to our next emergent theme.

Personal Relevance, Emotions, and Risk in STEM

We've combined these three themes here because they are inexorably tied in the consideration of STEM-related identity development.

Although not technically "emergent" in this study, since it was included in the conceptual framework as an important contributing factor to STEM-related identity development, the importance of personal relevancy exceeded our expectations. As revealed in the case-by-case analyses, the cross-case video analysis, the role model theme, and again here in the conflation issue -- personal relevance to STEM stands out as a critical factor among all others.

Coupled with personal relevancy were the girls' emotional and social connections to STEM. From the elation and joy demonstrated by Laura's union of STEM with her fervor for conservation to Kim's frustration and sadness as she struggled through chemistry to Gina's high stress time management challenge as she constantly sought balance in her quest to improve to Sofia's newfound pride and ambition for pursuing STEM unhindered -- emotions held the key to establishing personal relevancy for these girls. More than content presented (as we saw with Jane's baking chemistry and Mindy's sticklebacks, for example), what emerged from the journals and video narratives was the way STEM experiences made them feel about themselves that seems to have the greatest impact.

How they felt about STEM and their SciGirls-related experiences seemed to depend upon:

- The validation they received for being capable of doing STEM: including both a sense-of-agency and support (as in Sofia's story) as well as indicators of success through scores, grades (Gina), or acceptance into special programs (Laura's Galapagos trip)

- The social ties to close friends within STEM contexts: Even one important friend (in Mindy's case, her sister) could make the difference. Friends provide social acceptance of an expressed STEM-related identity in a social context where that is a challenge for girls and put quite simply, make STEM fun. As Sofia remarked, "*Me and my best friend [Sarah] love science so much. I'm glad I have someone to nerd out about science with. None of my other friends are very interested in STEM.*"

- Risk: Emotions were an important element of risk in all cases. The riskiness of a class or an activity for a given participant seemed to be a function of both low agency for that effort and the resulting anxiety upon deciding to try it anyway. This was most evident in Sofia's decision to take her 10th grade biology class that turned everything around for her, as well as her decision to take two simultaneous science classes in her junior year. It was also evident in Laura's volleyball inspired risk to take two science classes with a newfound sense of confident "cockiness."

For Gina, it was the ever-present risk of not getting good scores and not improving that shaped her emotions and governed her time management crises. In this sense, emotions served to signal the degree of risk and the degree of feelings of accomplishment or reward afterwards, including increased agency, pride, and self-efficacy. Without these pre and post emotions, risk would have little or no meaning. In terms of SciGirls, it should be recognized that risk has an inverse relationship with agency.

That is, when perceived risk is high, agency is low. Growth in positive STEM-related identity seemed to occur where perceived agency increased and perceived risk then correspondingly decreased. This was in concert with STEM learning but also role model or influencer experiences that helped grant participants permission (internal and external) to pursue STEM, deep self-reflection and meaning making about their relationship to STEM, and social bonding with STEM-related friends and like-minded communities or groups.

These findings are supported by the results of the quantitative part of the study which revealed "personal relevancy," "agency," and "emotional connection" as significant key composite operating to develop positive STEM-related identity for girls.

One final observation for the cross-case analysis: For the girls in this study, it seemed positive STEM-related identity was a fragile thing, even for those steeped in STEM from early childhood and through uncommon family and teacher support.

Forging a positive STEM-related identity is to swim against the stream in many cases and especially for girls in fields such as chemistry and math. Maintaining a positive STEM-related identity is sometimes an even greater struggle, through the maze of competing responsibilities and competing identities (gender identity included). And growing such an identity over time is a challenge rife with more pitfalls than supports.

Through the video narratives, interviews, and journals these girls produced and shared, we've gained insight to the processes important to the STEM-related identity development.

At the top of that list, across all cases in this study is personal relevance.

Conclusions

In terms of the study's research questions, the results indicate the following:

1) How does the experience of participating in all of the *SciGirls Strategies* project components impact girls' STEM-related identity development?

In general, female student experiences in classes led by ScigGirls-trained educators do indeed show results towards the development of more positive STEM-related identities according to the framework and research model. The results of both quantitative and qualitative components of this mixed methods study support the growth of STEM-related identity in seven of nine key composite indicators along with important insights of how lived experiences including those dimensions unfold in the personal lives of girls.

2) What are the impacts of individual project components, with a focus on the use of role models in classroom instruction?

The engagement of role models was revealed to be a significant and complex factor in the development of positive STEM-related identity for girls in the study. The use of female STEM by educators clearly showed advantages over no use, and further, in-person interaction showed advantage over video based and/or article reading exposure to role models. The case studies reveal the concept of "role models" to be somewhat alien to girls, in favor of what can best be termed "personal influencers" in their

lives. These were most often relatives or friends who had a high degree of personal relevancy for girls. Taken together these results indicate that educators may reveal untapped breadth and creativity in thinking about what kinds of role models to engage and how. Unpacking the concept of role models through the lens of multi-modal "influencers" may serve to expand both the nature of such interactions and ways to examine their impact of female (or male) STEM-related identity development.

Additionally, other student experiences based on program components emerged as important factors for STEM-related identity development, including personal relevancy, agency, risk, and emotional connection. Classroom based learning designs or activities that promoted pathways to these experiences appeared prominently in the case studies.

3) What modifications to the STEM identity framework are indicated by the findings?

The findings reinforce the importance of personal relevance, agency, and emotional connections related to STEM as important cognitive factors in STEM-related identity development. Risk experiences emerged as a critical factor within agency and emotional connections, whereas content confidence was not shown to be a dominant factor in formation of a positive STEM-related identity – although it was an important indicator for assessing it. Likewise, capacity to "do STEM" and/or understand it, along with demonstrated science concept, stated attitudes and self-efficacy and future choice aspirations were all revealed to be useful indicators of STEM-related identity development but not necessarily experiential factors in its

formation.

These results indicate a needed adjustment to the framework to delineate *indicators of* STEM-related identity development from experiential and cognitive *factors involved in the process of* STEM-related identity development. This significantly changes the framework from being one based on differentiating cognitive from behavioral components of STEM- related identity, towards a framework structured by measurable (or describe-able) processes vs. products or outcomes. This adjustment will also perhaps better serve practical applications for the future formulation and improvement of educational methods and philosophies such as SciGirls. An updated framework based on these findings and others will be the subject of an upcoming publication by the research team.

Finally, the results of this mixed methods study indicate the need for future research in the areas of personal relevancy and risk-experiences in the different domains of STEM learning. Although focused on girls, there is nothing inherently gendered in the formulation or outcomes of the SciGirls Seven strategies and teacher training under investigation here. While it is clear is that there are identity-based benefits to the girls in this study, there is an open question for how the same methods and strategies may benefit all students. It is

conceivable, for example, that there is indeed a differential advantage to these strategies for female students only. It is also possible such practices benefit and improve STEM-learning experiences for all students equitably. Only a future study designed to look across genders will be able to shed light on this question.

Additionally, the findings of the case studies also reveal numerous and varied struggles of the girls with the cultures of STEM in their classrooms and among their peers. The fact that we observe powerful revelation experiences when girls have breakthroughs in discovering how STEM is (and may even have always been) highly personally relevant in their lives, underscores the enormous gap in personal relevancy prior to such breakthroughs – call it personal irrelevancy. Does the same gap exist for boys? If so, is it experienced in the same ways? Can it be breached using the same methods? The answers to such questions will further inform our knowledge about what STEM learning experiences and methods work "for girls" vs. those that work for all – an important distinction for any projects aiming to develop expertise in gender-equitable STEM learning. Moreover, a focus on changing the STEM cultures that give rise to such experiences personal irrelevancy may just as important as gender-targeted programs for the successful development of positive STEM-related identities for girls.

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Appendix A. Composites and Corresponding Survey Items

<u>Personal Relevance Composite</u>
Response options: Not much like me/Slightly like me/Mostly like me/Extremely like me
  1. Science is important to me.
  2. [Reverse-coded] I actively avoid opportunities to do science-related things.
  3. Science is a big part of who I am and I what I do.

  Omitted sub-item: [Reverse-coded] I spend a lot of my free time doing things that are not related to science.

<u>Agency Composite</u>
Response options: Not much like me/Slightly like me/Mostly like me/Extremely like me
  1. I hope to have a science -related profession one day.
  2. [Reverse-coded] My role models are NOT involved in science.
  3. I admire scientists and people who work in science-related fields.
  4. [Reverse-coded] I see myself having a career that is NOT very much related much to science.

<u>Emotional Connection Composite</u>
Response options: Not much like me/Slightly like me/Mostly like me/Extremely like me
  1. I know most of my friends through my science-related activities.
  2. [Reverse-coded] I do NOT get very excited about doing science.
  3. Other people (family, friends, teachers) know that I like science.
  4. I enjoy or have fun doing science-related activities.

<u>Content Confidence Composite</u>
Response options: Not much like me/Slightly like me/Mostly like me/Extremely like me
  1. [Reverse-coded] I have a difficult time understanding science-related things.
  2. I feel that I can do science-related things quite well.
  3. [Reverse-coded] I rarely talk about science or my science-related activities with others.

<u>Enjoyment of Science</u>
Response options: Not much like me/Slightly like me/Mostly like me/Extremely like me
  1. I like to hear about new discoveries in science.
  2. I enjoy reading about science.
  3. It's fun to do science activities.
  4. I enjoy watching science shows.
  5. I like talking about science topics with others.
  6. I want to understand how things in science and nature work.
Response options: Strongly Disagree/Disagree/Not Sure/Agree/Strongly Agree*

7. I like to identify things in nature.

8. It's fun to collect things from outdoors.

*Items using this scale were converted to a 4 point-scale, where "Not Sure" responses were coded to missing

Science Career Interest

Response options: Strongly Disagree/Disagree/Not Sure/Agree/Strongly Agree

1. I am able to do well in activities that involve: (Science)

2. I am able to complete activities that involve: (Science)

3. In my future career, I plan to use: (Science)

4. I will work hard in my classes involving: (Science)

5. It will help me in my future career, if I do well in: (Science)

6. My parents would like it if I choose a career related to: (Science)

7. I'm interested in careers that use: (Science)

8. I like activities that involve: (Science)

9. I have a role model in a career related to: (Science)

10. I would feel comfortable talking to people who work in careers related to: (Science)

11. I know of someone in my family with a career related to: (Science)

Technology Career Interest

Response options: Strongly Disagree/Disagree/Not Sure/Agree/Strongly Agree

1. I am able to do well in activities that involve: (Technology)

2. I am able to complete activities that involve: (Technology)

3. In my future career, I plan to use: (Technology)

4. I will work hard in my classes involving: (Technology)

5. It will help me in my future career, if I do well in: (Technology)

6. My parents would like it if I choose a career related to: (Technology)

7. I'm interested in careers that use: (Technology)

8. I like activities that involve: (Technology)

9. I have a role model in a career related to: (Technology)

10. I would feel comfortable talking to people who work in careers related to: (Technology)

11. I know of someone in my family with a career related to: (Technology)

Engineering Career Interest

Response options: Strongly Disagree/Disagree/Not Sure/Agree/Strongly Agree

1. I am able to do well in activities that involve: (Engineering)

2. I am able to complete activities that involve: (Engineering)

3. In my future career, I plan to use: (Engineering)

4. I will work hard in my classes involving: (Engineering)

5. It will help me in my future career, if I do well in: (Engineering)

6. My parents would like it if I choose a career related to: (Engineering)

7. I'm interested in careers that use: (Engineering)

8. I like activities that involve: (Engineering)

9. I have a role model in a career related to: (Engineering)

10. I would feel comfortable talking to people who work in careers related to: (Engineering)

11. I know of someone in my family with a career related to: (Engineering)

Mathematics Career Interest

Response options: Strongly Disagree/Disagree/Not Sure/Agree/Strongly Agree

1. I am able to do well in activities that involve: (Math)

2. I am able to complete activities that involve: (Math)

3. In my future career, I plan to use: (Math)

4. I will work hard in my classes involving: (Math)

5. It will help me in my future career, if I do well in: (Math)

6. My parents would like it if I choose a career related to: (Math)

7. I'm interested in careers that use: (Math)

8. I like activities that involve: (Math)

9. I have a role model in a career related to: (Math)

10. I would feel comfortable talking to people who work in careers related to: (Math)

11. I know of someone in my family with a career related to: (Math)

Appendix B. Descriptive Statistics for Survey Items

Item		Treatment			
		Not much like me	Slightly like me	Mostly like me	Extremely like me
2. Science is important to me.[3]	Pre	8	17	46	30
	Post	5	18	46	30
3. I hope to have a science-related profession one day.[1,3]	Pre	10	31	38	19
	Post	9	30	33	27
4. I do NOT belong to any science - related groups, clubs, or organizations.[2,4]	Pre	47	22	14	15
	Post	58	24	4	12
5. I know most of my friends through my science-related activities.[3]	Pre	37	34	20	9
	Post	31	33	18	16
6. I do NOT get very excited about doing science.[3]	Pre	50	27	14	9
	Post	60	24	10	5
7. I actively avoid opportunities to do science-related things.[1,4]	Pre	53	33	9	4
	Post	60	22	10	6
8. Science is a big part of who I am and I what I do.[3]	Pre	13	35	37	14
	Post	11	40	30	17
9. I spend a lot of my free time doing things that are not related to science.[4]	Pre	15	35	38	11
	Post	11	30	34	23
	Pre	17	26	36	20

10. Other people (family, friends, teachers) know that I like science.[1,4]	Post	13	26	35	24
11. My role models are NOT involved in science.[1,3]	Pre	28	39	24	9
	Post	32	33	16	17
12. I admire scientists and people who work in science-related fields.[3]	Pre	10	30	36	23
	Post	11	28	31	29
13. I have a difficult time understanding science-related things.[3]	Pre	39	42	15	4
	Post	38	41	18	2
14. I feel that I can do science-related things quite well.[3]	Pre	6	21	42	31
	Post	3	24	45	28
15. I see myself having a career that is NOT very much related much to science.[2,3]	Pre	30	36	26	6
	Post	27	46	17	10
16. I rarely talk about science or my science-related activities with others.[1,3]	Pre	20	45	25	10
	Post	25	37	26	11
17. I enjoy or have fun doing science-related activities.[4]	Pre	3	12	46	39
	Post	1	17	32	48

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