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RESEARCH ARTICLE

Recognition Matters: the Role of Informal Science Education Programs in Developing Girls' Science Identity

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Abstract

Girls and women remain stubbornly underrepresented in certain science fields. This underrepresentation begins as early as late elementary school as girls begin to (dis)identify with science because they do not see themselves as potential scientists because they cannot recognize themselves as belonging (internal recognition) and/or others do not recognize them as scientists (external recognition). Informal science education (ISE) programs have shown some promise for improving girls' recognition as it relates to science. However, evidence is mixed on the influence of these programs because there is no commonality in structure or goal for programs that are compared. Hence, we know how specific programs influence girls' internal and external recognition, but we do not know how this could be successfully replicated. The SciGirls organization has developed a set of research-based gender-equitable strategies that guide their programs and activities to improve girls' identification with science disciplines. To better understand the efficacy of these strategies on participating girls' internal and external recognition, we conducted a linear regression to compare pre- to post- external and internal recognition responses. The SciGirls programs we investigated improved girls perceived external recognition; however, their own internal views of themselves as science people did not change significantly. The findings support the use of the SciGirls Strategies for building external recognition for girls, which is an important piece of science identity development.

Keywords Science identity · Informal science education · Girls · SciGirls

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Introduction

Women represent less than one-third of the science and engineering (SE) workforce (NSF, 2021). This underrepresentation leads to a lack of diverse and innovative ideas that affects all citizens (National Research Council [NRC], 2009; 2010). The underrepresentation of girls and women in SE has multiple causes. Girls begin to question whether they belong or can be successful in SE during elementary and middle school due to perceptions that these fields are predominantly white and male leading them to question whether they are (or can be) scientists and recognized as such by others (Archer et al., 2017; Calabrese Barton et al., 2013; Carlone et al., 2014; Master et al., 2016; Ryu et al., 2019; Tan et al., 2013). We define the concept of belonging as identifying with science (i.e., science identity) which can influence girls' persistence in these fields. Because this decline in identification for girls begins as early as 5th and 6th grade (late elementary school/early middle school), this is a crucial age to study science identity development (Archer et al., 2012; Kim et al., 2018; Poirier et al., 2009; Tai et al., 2006). In particular, informal science education (ISE) programs have been found to be influential in improving girls' science identity (Chan et al., 2020; Kitchen et al., 2018; McCreedy & Dierking, 2013), by creating a third space for marginalized youth—including girls of all races—to connect school science and their daily lives, allowing them to begin to see themselves and be recognized by others as scientists (Calabrese Barton et al., 2013; Hughes et al., 2021; Ryu et al., 2019; Todd & Zvoch, 2019). The results of qualitative studies on the role of ISE programs are compelling; however, we do not have many quantitative studies that help us to understand if successful practices within individual ISE spaces can be replicated across multiple programs. The purpose of our research study is to address this issue by studying the impact of a common set of gender-equitable strategies used to train educators and structure activities across eleven all-girl ISE program on participating girls' science identity as measured through internal and external recognition.

Theoretical Framework: Recognition as a Key Piece to Science Identity

Recognition is a key part of our current understanding of science identity. The initial concept of science identity was introduced by Carlone and Johnson (2007) in their study of undergraduate women and focused on the interconnectedness each woman's science competence development, the performance of these competencies and the recognition received for these performances. Since then, researchers have highlighted that recognition—both internal and external—is a crucial and not well understood part of science identity development, particularly for marginalized groups in science at the key transition point of late elementary and early middle school (Avraamidou, 2019; Calabrese Barton et al., 2013; Kim et al., 2018; King & Pringle, 2019).

Science identity is affected by individual decisions, social interactions and the interpretations of these interactions and decisions over time (Avraamidou, 2019). Consequently, science identity development is context-specific and changes at any given moment, particularly in response to how it is accepted or rejected by others, thereby making recognition an important piece of the science identity puzzle we as researchers need to better understand (Calabrese Barton et al., 2013; Holland et al., 1998; Pattison et al., 2020). For girls in late elementary and middle school, science recognition traditionally comes from formal classroom teachers and family members (Carlone et al., 2014; Hill et al., 2017), but for many girls, particularly girls of color, stereotypes associated with gender and race and who belongs in science affect how they are recognized (e.g., assigning girls as note-takers and complementing them for their organizational skills rather complementing their science skills) (Archer et al., 2015; Collins, 2018; Dawson et al., 2019; Master et al., 2016). This in turn makes it more difficult for girls to see themselves as science people.

ISE programs can be a positive influence on girls' internal and external recognition as scientists, leading to positive science identity development (Calabrese Barton et al., 2013; Hughes & Roberts, 2019; Roberts & Hughes, 2019; Talafian et al., 2019). ISE spaces give girls opportunities to meet and interact with role models and be recognized for the work they do as scientists, removed from the stereotypes that may permeate the formal science classroom (Calabrese Barton et al., 2013; Caraballo, 2019; Hughes et al., 2020; McCreedy & Dierking, 2013; O'Brien et al., 2017; Ryu et al., 2019; Todd & Zvoch, 2019). However, not all ISE programs are structured the same way, making it more difficult to determine if successful interventions in one program can be replicated more broadly. The purpose of our research study is to address this issue by studying the impact of a common set of gender-equitable strategies used to train educators and structure activities across eleven all-girl ISE program on participating girls' internal and external recognition. The research question guiding this project is as follows: Are there observable changes in science identity as measured by internal and external recognition for girls who participated in one of eleven SciGirls Informal education programs?

Literature Review

In the last decade, recognition has become a key part of science identity development. Recognition can include one's sense of how others view them in relation to science (external recognition) and their own recognition of themselves as belonging in science (internal recognition). Lucy Avraamidou has reiterated the role that the politics of science play in who is recognized and how that recognition is internalized based on individuals', particularly girls' and women's, marginalization in society and science (2020). Avraamidou's work has focused on adult women's trajectories in science, concluding that recognition matters but we are still not sure whose recognition matters more and in what contexts it is more influential. For example, Hazari and her colleagues (2017) found that for the 962 undergraduate women physics majors they surveyed, their high school physics teacher's recognition had the most impact on their science identity in college.

This result highlights the long-lasting influence that external recognition can have on girls' and women's internal view of themselves as scientists.

Other studies have pointed to the importance of power dynamics and individual identities in how recognition is presented and taken up by adults in science (Johnson et al., 2011; Rodriguez et al., 2019). Johnson and her colleagues interviewed three women of color in graduate science degree programs. The authors found that the recognition that the women experienced was dependent on the cultural norms, values, and stereotypes inherent to the science departments the women were a part of, leading the women to only feel like a scientist and be recognized as such when they mimicked the cultural norms of scientists (i.e., white and male). Similarly, Rodriguez and her colleagues interviewed 17 Latina college science majors focusing on the women's recognition of themselves as scientists and the external recognition they received from others. The authors found that recognition from disciplinary experts within one's college department was influential for the participants, which often constrained how these women were recognized due to their outsider status as Latinas. Avraamidou argues that "the process of becoming a science person or forming a science identity is not something that happens within individuals but is something that happens to individuals through recognition" (2020; p 14).

These studies point to the role of cultural and social domains of power on adult women's internal and external recognition and developing science identity, but studies have demonstrated that this same political and cultural influence occurs at the middle school level as well (Dawson et al., 2019; Talafian et al., 2019; Wade-Jaimes & Schwartz, 2018). For space constraints, we highlight three studies that measured identity through recognition in informal science education spaces (i.e., Dawson et al., 2019 museum exhibits; Talafian et al., 2019 in a summer camp and Wade-Jaimes & Schwartz, 2018 in formal science classroom spaces). In Dawson et al.'s observational ethnographic study, the authors found that participants' (middle school girls of color) attempts to try on various science identities during their engagement in a science museum exhibit were constrained by the implicit bias and stereotypes their peers and educators held. These biases prevented the girls from being recognized as science people (e.g., they were deemed too loud or silly to be science people). Talahian and her colleagues focused on how youth in a physics summer camp recognized themselves as scientists. Because of the small sample size, the quantitative pre/post comparison was not significant, but the qualitative results demonstrated that the youth saw themselves more as astrophysicists by the end of the camp because they were able to learn more about astrophysics careers and meet scientists in these fields. However, the authors acknowledge that the majority of these participants were boys. Wade-Jaimes and Schwartz conducted an ethnography focusing on the influence of discourses within a science classroom on African American middle school girls' recognition as science people (2018). The authors found that girls' science performances during these discourses (e.g., enthusiastic, social, playful, and resilient) were not recognized as authentic science performance by their teachers. These studies demonstrate that broader cultural biases of who belongs in science permeate into both formal and informal science education spaces even at the early middle school age. These studies also show that qualitative measures have provided more details on the role of recognition, helping us to realize its value for further study.

Current Understanding of ISE Programs' Role on Recognition

ISE spaces can help girls combat stereotypes and see themselves as scientists as well as be recognized by experts as such. However, studies on recognition have mainly focused on the influence of a small number of youths in one program (e.g., Talafian et al., 2019), making it difficult for researchers to determine if successes in one program can be replicated in other programs. Quantitative research can provide a broader understanding of ISE spaces' role on girls' internal and external recognition as a key piece of science identity development to ensure that resources invested into these programs are addressing the issues that affect girls' ability to identify with science (Todd and Zvoch, 2019). However, few studies have focused on science identity as a measured outcome. For example, Conrad et al. (2018) and Schmidt et al. (2020) both conducted pre/post quantitative comparisons of multiple summer camps on participating students' sense of science competence. In both studies, the camps compared were very different from each and the results were not statistically significant. This does not mean that the camps are not successful at improving one's sense of competence—a metric for identity—rather it requires a comparison across camps that are more similar to see if they influence girls' science identity, particularly the valuable components of internal and external recognition.

The authors have conducted two such quantitative studies (Hughes & Roberts, 2019; Roberts & Hughes, 2019), focusing on the influence of ISE programs on girls' science identity as measured through internal and external recognition along with self-efficacy. We utilized the same survey instrument for both studies derived from the Assessing Women in Engineering Middle School Core Survey (AWE, 2008) and The Is Science Me? Survey created by Aschbacher et al. (2010) as metrics for science identity and science self-efficacy. The science identity portion of the survey included questions that measured students' perceptions of internal and external recognition as science people. These studies included pre- post-survey comparisons for youth who participated in summer camps over a 4-year period. Both indicated that the programs influenced girls' self-efficacy and identity, but our results were not statistically significant nor could we determine what specific programmatic aspects of the camps might be influencing the girls (Hughes & Roberts, 2019; Roberts & Hughes, 2019).

Based on the above literature review, one can see how current research on ISE programs is struggling to show broader patterns regarding their influence science identity so that they can be replicated and tested across more diverse audiences and programs. We as ISE researchers need to better understand the extent to which ISE programs are influencing girls' science identity, particularly the key recognition piece, so that we can improve girls' persistence in science and increase the diversity of ideas in science education and disciplines. The present study addresses this concern and leverages the survey instrument developed by the authors in previous studies (Hughes & Roberts, 2019; Roberts & Hughes, 2019). In the present study, we examined the impact of eleven

SciGirls ISE programs on participating girls' sense of internal recognition and external recognition as science people. All of these programs used the same research-based strategies for improving girls' interest in STEM—the SciGirls gender-equitable strategies (Billington et al., 2014).

Methodology

Science Identity Focus of the ISE Programs

The eleven SciGirls programs we studied were guided by the SciGirls gender-equitable strategies, heretofore referred to as the SciGirls Strategies. The SciGirls Strategies were developed based on a critical literature review of best practices in science identity development for girls (Billington et al., 2014). The goal of the SciGirls Strategies is to improve girls' science identity, defined as their sense of belonging and perceived future success in science (Calabrese Barton et al., 2013). Educators who led each of the SciGirls programs in our study were trained in the SciGirls Strategies and were taught: (1) how to engage girls in activities that provide opportunities for them to be recognized as science people; and (2) how to effectively recognize these performances. Table 1 provides details on each of the SciGirls Strategies and explicitly outlines how they connect to internal and external recognition.

Participating SciGirls Programs

In order to be part of the study, each SciGirls program had to have at least one of their lead educators take part in 2-day SciGirls Strategies training conducted by the SciGirls national organization. During this training, educators engage with experts to facilitate SciGirls activities (http://www.scigirlsconnect.org/). The SciGirls website highlights how the strategies are explicitly applied during the activities. Each SciGirls program is also encouraged to create a learning environment where all participants feel valued and safe (Simpkins et al., 2017). The project evaluation team provided confirmation from educators that the strategies were used over the course of their respective programs. Based on the evaluation report, the educators found the strategies to be clear, valuable, and relatively easy to implement, and indicated that they used the strategies to a "considerable" or "great extent" during their respective program. Although the SciGirls programs differed in location, length of time, and number of participants, all used the same SciGirls Strategies to structure their activities. Consequently, each of these programs was created based on a shared structure and created a community of practice wherein girls should have opportunities to be recognized and educators have been trained to recognize girls in ways that we hypothesize should lead to stronger science identities (Lave & Wenger, 1991).

Table 1 SciGirls gender-equitable strategies and their relationship to recognition

Description of strategy	Relationship to recognition framework
Strategy 1: Girls benefit from collaboration, especially when they can participate and communicate fairly. Girls thrive when they work together to make science, technology, and engineering an intentionally social experience	The intentional social experience means that girls will have opportunities to be recognized by educators and peers which can benefit **internal recognition and external recognition**
Strategy 2: Girls are motivated by projects they find personally relevant and meaningful. Girls become motivated when they feel they can make a difference. If girls see science as relevant to their own lives, their attraction to these subjects is likely to increase	Making STEM relevant means making it personal. If girls can personally connect to science, they may see themselves more as a science person which can benefit **internal recognition**
Strategy 3: Girls enjoy hands-on, open-ended projects and investigations. Educators and role models can encourage and promote exploration, imagination, and invention by encouraging girls to ask questions and find their own paths for investigation	Educators are explicitly asked to recognize girls through questions and open-ended projects which can benefit **internal recognition and external recognition**
Strategy 4: Girls are motivated when they can approach projects in their own way, applying their creativity, unique talents, and preferred learning styles. Girls should take ownership of their own investigations, collecting data, solving problems, and communicating their findings and results	Making science personal makes it more relevant. If girls can personally connect to science, they may see themselves more as a STEM person which can benefit **internal recognition**
Strategy 5: Girls' confidence and performance improves in response to specific, positive feedback on things they can control—such as effort, strategies, and behaviors. Self-confidence can make or break girls' interest in science. Adults can support girls' efforts by encouraging their problem-solving strategies; allowing them to struggle and/or fail; emphasizing that their skills can be improved through practice	Educators are explicitly asked to recognize girls' growth mindset moving away from the "good girl student" prominent in school and helping them see what they are doing as science, thereby providing opportunities for improvement in **internal recognition and external recognition**
Strategy 6: Girls gain confidence and trust in their own reasoning when encouraged to think critically. Educators should cultivate an environment that encourages creative thinking, questioning, trial and error, and authentic, personal discoveries	Educators are explicitly asked to encourage girls in their critical thinking and trial and error– a form of recognition that can benefit **internal recognition and external recognition,** even when working through problems or mistakes
Strategy 7: Girls benefit from relationships with role models and mentors. Seeing women who have succeeded in science helps inspire and motivate girls. By hosting field trips and visiting programs, role models tangibly demonstrate how girls can succeed	During these role model and mentoring experiences, girls have opportunities to be recognized by women in science and see themselves as science people, potentially benefitting their **internal recognition and external recognition**

Recruitment of Participants

Each SciGirls site received $1000 to buy supplies for the program and had to commit to holding a program lasting 16 + h for at least 10 girls (~ ages 10–15). Each program conducted their own recruitment for participants. Programs could include boys. Being a participant in the camp did not automatically mean that girls were included in the research study, hence the range in our research participants ($n = 2–39$) across all sites in Table 2. To recruit research study participants, the authors recorded a video explaining the project and drafted a letter for each SciGirls program to send/show to parents and girls. Participants were encouraged to contact the authors if they had questions. We relied on educators/administrators at each site to collect the consent (parent) and assent (child) forms. Only those youth who had signed consent and assent forms were included in the study. Some programs forgot to send consent forms home before the camp began and those programs were not included. Some sites submitted only one of the two required forms for individual youth, and these youth were also excluded from the analytic sample.

The participating SciGirls programs were held between 2017 and 2019. Five afterschool programs and six summer camps participated in the study. Table 2 includes a complete list of the programs, the number of days the program ran, whether it was an afterschool program or summer camp, the type of group who organized it, and the state, as well as the pre- and post-science identity, means.

The demographics of the individuals who took part in our study at each site can be found in Table 3.

Survey Instruments

The main data source for this study were the youth's pre- and post-survey responses to the science identity[1] survey (Hughes & Roberts, 2019; Roberts & Hughes, 2019). Youth at each site were given a survey before and after their respective program. Because we were focused on what changes occurred in science identity, we only included girls who completed both a pre- and post-survey in the final analytic sample, resulting in a total of 148 girls across the eleven programs.

Our survey included questions related to one's internal belief that they are science person (internal recognition) and their sense that others recognized them a s a science person (external recognition). All survey items were measured on a five-point Likert scale, with 1 being "strongly disagree" and 5 being "strongly agree." Any negatively worded questions were reverse coded before being used to calculate scale scores. Table 4 provides more details on the survey questions for science identity as well as scale reliabilities and reverse coded items.

These survey questions were derived from multiple instruments (Aschbacher et al., 2010; Assessing Women in Engineering, 2008; Callero, 1985). The initial survey was deemed too long for campers in an ISE setting by the authors and the project's advisory team. Consequently, the authors conducted exploratory factor analysis as an item-reduction technique. Five scales emerged from the EFA analysis, and factors included items which achieved at least a 0.4 factor loading. These EFA results served as preliminary evidence working towards the validity of the

[1] The authors use capital letters when referring to the survey categories and lower case when referring to general science identity, or recognition concepts.

Table 2 SciGirls program information and descriptive statistics

Program (schedule)	Site type	Organization type	State	N of research participants	Science identity pre	SD	Science identity post	SD	*d*
Program 1 (regularly over a semester)	Afterschool	Community group	Minnesota	7	3.3	1.01	3.1	0.95	-0.20
Program 2 (2 days summer)	Camp	University-based	Texas	30	3.3	0.89	3.3	0.76	0.00
Program 3 (5 days summer)	Camp	Community group	North Carolina	5	3.1	0.73	3.1	0.62	0.00
Program 4 (regularly over a semester)	Afterschool	Community group	Connecticut	3	2.2	1.25	3.1	1.80	0.58
Program 5 (10 days summer)	Camp	University-based	Florida	37	4.0	0.67	4.0	0.81	0.00
Program 6 (regularly over 1 month)	Afterschool	School	New Jersey	13	2.8	0.83	3.2	0.88	0.47
Program 7 (5 days summer)	Camp	Aquarium	Florida	39	3.8	0.63	4.1	0.77	0.43
Program 8 (regularly over a semester)	Afterschool	Community group	New Mexico	4	3.5	0.38	3.8	0.65	0.56
Program 9 (regularly over a semester)	Afterschool	Community group	Minnesota	4	3.0	0.60	3.1	0.89	0.13
Program 10 (5 days summer)	Camp	University-based	Montana	2	4.1	0.94	4.0	0.24	-0.15
Program 11 (5 days summer)	Camp	Community group	New York	4	2.9	1.14	3.4	0.55	0.56

Table 3 Demographics of analytic SciGirls sample

	n	Percent
Grade		
5th	29	20.1%
6th	36	25.0%
7th	52	36.1%
8th	21	14.6%
9th	6	4.2%
Gender		
Male	5	3.4%
Female	141	95.3%
Other	1	0.7%
Race and ethnicity		
Asian	13	8.8%
Black	35	23.6%
Hispanic or Latino/a	25	16.9%
White or Caucasian	70	47.3%
Enrollment in honors courses		
Yes	86	59.3%
No	59	40.7%

instrument, but further validation work has not yet been conducted. To address this, we calculated scale reliabilities for each of the scales to ensure they met the minimum standard of being internally consistent. This paper focused on the recognition factors most directly related to the SciGirls Strategies: internal recognition and external recognition.

Analytic Methods

The overarching research question driving this paper was: Are there observable changes in science identity as measured by internal and external recognition for girls who participated in one of eleven SciGirls Informal education programs? Therefore, the outcome variable for the study was girls' science identity (Hughes & Roberts, 2019; Roberts & Hughes, 2019). The science identity scale was comprised of two subscales: internal recognition—seeing oneself as a science person or scientist; and external recognition—believing that others see one as a science person or scientist. These categories allowed us to determine changes in recognition based on participation in one of eleven SciGirls programs.

To accommodate for the small sample size, a related sample Wilcoxon signed-rank test was used to test for overall changes from pre- to post-program on the three outcome variables: external recognition, internal recognition, and overall science identity. Subsequently, change scores for each scale were analyzed using linear regression to test for any impacts of demographic characteristics. The demographic characteristics were self-reported gender, race, ethnicity, enrollment in honors

Table 4 Science Identity Scales and Items

Scale	Subscale	Items
Science identity (α = 0.905)	Internal recognition (α = 0.832)	• Science is something I rarely even think about. (reverse coded) • I would feel a loss if I were forced to give up doing science • I really don't have any clear feelings about science. (reverse coded) • Science is an important part of who I am • Being a scientist is an important part of my identity • No one would really be surprised if I just stopped doing science. (reverse coded)
	External Recognition (α = 0.904)	• Many people think of me in terms of being a scientist • Other people think doing science is important to me • It is important to my friends and relatives that I continue as a scientist • Many of the people that I know expect me to continue as a scientist

classes, and grade in school. The inclusion of all of these characteristics in one regression model for each outcome variable allowed us to parse out impacts of each characteristic independent of the others.

Results

The overall means for each scale either remained stable from pre- to post-program or increased. In order to test for significance in the changes from pre- to post-survey for overall science identity, internal recognition, and external recognition, we conducted a related samples Wilcoxon signed-rank test. Of the three scales we tested, one had a statistically significant difference from pre- to post-program: external recognition. Results of these analyses are presented in Table 5. The science identity subscale scores indicate that girls' views of themselves as science people did not significantly change, but their idea of how much other people perceived them as science people did change. Consequently, the participants felt recognized by others

Table 5 Related sample Wilcoxon signed-rank test results for scales and subscales

	Mean pre	Pre SD	Mean post	Post SD	*d*
Science identity	3.50	.874	3.58	.861	.09
Internal recognition	3.77	.845	3.78	.857	.02
External recognition	3.23	1.052	3.36	0.997	.12*

$^{*}=p<0.05$, $^{**}=p<0.01$, $^{***}=p<0.001$

Table 6 Regression results for change in science identity

Demographic categories	*β*	Standard error
Gender	−.196	.263
Asian	−.093	.209
Black or African American	−.042	.151
White or Caucasian	−.068	.145
Hispanic or Latino/a	.198	.133
Honors enrollment	−.031	.108
Grade	−.164**	.049

$^{*}=p<0.05$, $^{**}=p<0.01$, $^{***}=p<0.001$

(e.g., educators, role models, peers) during their respective SciGirls program which resulted in improved external recognition.

To account for factors that influence science identity (e.g., gender, race, ethnicity, enrollment/non-enrollment in honors classes, and grade in school), we ran linear regression analyses with these variables as controls and girls' change in scores for science identity as the outcome variables. Results from these analyses are presented in Table 6. For science identity, we found no significant differences by gender, race, or honors enrollment. However, we found that grade in school did have a significant relationship to changes in science identity.

The negative coefficient for school level/grade in predicting changes in science identity indicates that older youth reported less growth in science identity. These results suggest that as individuals progress through school, their growth rates in science identity may slow or even decline. Figure 1 shows the average pre- and post-science identity scores for students at each grade level. In grades 5 and 6, we see the average post-scores are higher than the average pre-scores, but not in grades 7 and 8. However, the slopes for the overall trend lines for pre- and post-program science identity scores are both positive.

Discussion

Our study highlights that participation in SciGirls summer camps and afterschool programs, all utilizing the SciGirls Strategies, can positively increase participating girls' science identity. Our data analysis shows that the girls' perceptions that others

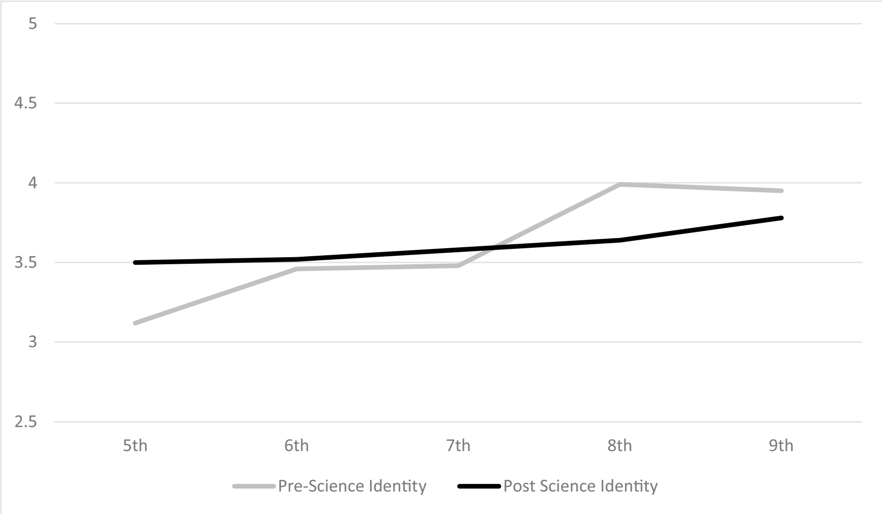

Fig. 1 Average pre- and post-program science identity scores by grade

recognized them as science people improved after their participation in their respective SciGirls program. External recognition (i.e., recognition by important others) is a key component in developing girls' (and women's) science identity (Avraamidou, 2020; Dawson et al., 2019; Johnson et al., 2011; Rodriguez et al., 2019; Talafian et al., 2019; Wade-Jaimes & Schwartz, 2018). Our study provides empirical evidence building on qualitative research that shows that relatively short-term programs (1-week or more) can positively influence girls' beliefs that others see them as scientists (Calabrese Barton et al., 2013; Carlone et al., 2014; Godwin & Potvin, 2017; Kim et al., 2018; Simpkins et al., 2017; Talafian et al., 2019). Educators, role models, mentors, and peers play a crucial role in helping girls to feel like they belong (Calabrese Barton et al., 2013; Carlone et al., 2015; Djonko-Moore et al., 2018). For example, the SciGirls strategies that ask educators to provide specific and positive feedback along with encouraging them to think critically may be how external recognition was increased among the girls as they had opportunities to be supported and validated in their science learning and doing. Although more research is needed, the findings from our study show promising results for the implementation of the SciGirls Strategies for training educators to be positive external recognizers and for developing programs that help girls to feel that others see them as science people.

Surprisingly, this increase in external recognition was not seen in the girls' internal perceptions of themselves as science people (i.e., internal recognition). This is particularly troublesome, as research has shown that internal recognition as a science person can serve as a source of resilience when girls move into adulthood and meet resistance in their science trajectory, particularly for girls and women of color (Avraamidou, 2020; Carlone & Johnson, 2007; Ibourk et al., 2022). Although our study did not find differences across race and ethnicity for girls' internal perception and science identity growth, past research has indicated that the intersectional identities of race and gender create differing experiences for girls of color and can make their science identity negotiations harder (Carlone et al., 2014, 2015; Dawson et al., 2019; Hughes et al., 2021; Ibourk et al., 2022; Ireland et al., 2018; Jones, 2019; Wade-Jaimes & Schwartz, 2018). Therefore, we urge other researchers to continue to focus on the intersectionality of science identity development across race, gender, and other salient identities to determine how educators can improve their own recognition of girls as valued science contributor. This research will help ISE programs become more inclusive of various identities that are currently marginalized in science.

Another interesting, although not significant, finding was the difference between 5th- and 6th-grade girls' science identity growth compared to 7th and 8th graders. This latter group had higher science identity than their younger peers but showed declines from pre- to post-program. This decrease in science identity as girls continue through their educational journey has been found in other studies (Hughes & Roberts, 2019; Roberts & Hughes, 2019; Tan et al., 2013). Consequently, our finding along with other research indicates that ISE programs should consider the age of their participants when designing their curriculum if they want to improve girls' science identity. Older girls (8th and 9th grade) have more experience with the racism and sexism inherent in both our education systems and science disciplines simply because they have been negotiating their various identities in these spaces for longer. Research shows that formal science classroom spaces, as well as ISE spaces, may not be as inclusive or supportive as the SciGirls programs (Dawson et al., 2019; Hughes et al., 2021; Simpkins et al., 2017; Wade-Jaimes & Schwartz, 2018), particularly for girls of color who must battle the dueling stereotypes of race and gender (Ireland et al., 2018). As girls progress through school, they begin to lessen their internal recognition of themselves as a science person due to a variety of factors including gender and racial stereotypes related to who belongs in science and the implicit biases of educators and other socializers (Archer et al., 2017; Ireland et al., 2018; Lock & Hazari, 2016; Master et al., 2016; O'Brien et al., 2017). ISE programs can be a positive intervention for girls at all ages but may be most important at these older ages when girls begin to question their belonging in science. The systemic challenges to girls' science identity as they move through science education may demand more in-depth and explicit gender-equitable strategies to strengthen science identity. The results from our study show that the SciGirls Strategies have real promise for improving girls' recognition as science people in ISE programs. However, programs for older girls should investigate how the declining internal recognition among older girls can be strengthened to improve their resolve as they return to science settings and a society that may not give them the same support as ISE programs can.

Limitations

In this study, we had limitations based on our sample size as well as conducting a research study of programs that exist across the nation. We will first identify the limitations from a research perspective. For the significant findings in our analyses, we found small corresponding effect sizes. However, recent research has indicated that this is relatively common in educational settings, especially in settings where training is provided to educators, who then provide an intervention to youth, as was the case in our study (Kraft, 2020). Additionally, a meta-analysis conducted by Cheung and Slavin (2016) found that studies with larger effect sizes are oversampled in the published literature at the expense of studies with smaller reported sample sizes. Kraft (2020) recommends that effect sizes be taken into consideration with cost and scalability of the intervention.

The multi-site nature of this program introduced new challenges in the data collection process that are not present in single-site studies. We found collecting data across sites to be difficult because it was difficult to get buy in from the participants, especially compared to our experiences in administering single-site studies (Hughes & Roberts, 2019; Roberts & Hughes, 2019). All of the sites preferred to introduce the research study on their own without a live presentation by the researchers, to minimize the presence of outsiders and create a local community within each program. Additionally, the sites were inconsistent in their provision and collection of the consent forms, which meant we had survey data for some students, but no consent or assent forms, which resulted in the exclusion of their survey data. Future researchers need to consider how they will create trust and ensure quality data collection at ISE sites that may be limited in technology and/or time, especially when it is not feasible to have a member of the research team at each site on the days when data is collected.

Future Research

Our study does indicate that the SciGirls Strategies can improve girls' sense of external recognition—a key component of science identity—across ISE programs; however, it does not tell us how this change is occurring. To determine how the strategies and/or programs influence science identity, more in-depth qualitative studies, as well as larger sample size quantitative studies, would be necessary. The empirical results presented in this paper are just the beginning of the possibility of scaling the SciGirls Strategies to other SciGirls programs to further test the impact of those strategies on girls' science identity development. Additionally, due to the relatively small sample size and observational nature of the study, it is not advisable to generalize these findings to all ISE programs. These results serve as preliminary evidence highlighting the need for further investment in and investigation of these strategies.

Conclusions and Significance

In conclusion, recognition is a key component of science identity. Research has shown mixed evidence for the impact of ISE programs because of limitations to single site studies or an inability to compare across disparate programs. Our study aimed to address this issue by determining the impact of the SciGirls gender-equitable strategies as a common framework across eleven SciGirls ISE sites on participating girls' external and internal recognition as key components of science identity development. The results showed that the girls improved their external recognition. By studying SciGirls programs that all utilized the same strategies to train educators and develop activities, we have preliminary data that shows the positive impact the SciGirls Strategies can have on girls' science identity as seen through increased external recognition even in programs lasting as little as a week.

The SciGirls Strategies show real promise if enacted (and studied) by other ISE organizations. ISE programs can take this framework and easily apply it to their respective programs whether they are focused on a particular discipline, age group, or region. The SciGirls national program already has regular trainings in place for educators, and a train-the-trainer model in place that allows the SciGirls Strategies to be easily scaled at relatively low-cost to interventions across the nation. The newfound ubiquity of virtual trainings further increases the affordable scalability of the SciGirls Strategies and the train-the-trainer model. The insights gained from this study show that the SciGirls Strategies are a tool that should continue to be utilized and refined to help provide an overarching structure for ISE spaces. This has exciting potential for programs and their impact on making girls feel like they belong in science. Further implementation and testing of the SciGirls Framework will only serve to strengthen the SciGirls Strategies' overall promise.

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Declarations

Conflict of Interest The authors declare no competing interests.

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