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RESEARCH ARTICLE

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Much to do about identity: Successful women in science reflect on their school years

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Abstract

This study presents the recollections of 12 successful women in science during their school years before postsecondary education. The participants shared detailed descriptions of their science experiences through three semi-structured interviews. An identity works conceptual framework consisting of figured worlds, positioning, and agency constructs to portray the complex dynamics of their experiences was used to analyze the data. The following four themes emerged from the data analysis: participants had an early interest in mathematics and science; they were "stubbornly" persistent in science-figured worlds; they engaged in science-figured worlds beyond school; and they positioned themselves as science leaders. These findings add to the evolution of science identity development theoretical models because they are from a nondeficit perspective. Participants engaged in identity work that advanced their science identities despite the gender biases in science-figured worlds. From a practical stance, girls and women could employ the agentic and positive positioning identity work that the findings show to develop their science identity in educational contexts. Science educators and researchers are encouraged to structure figured worlds where girls feel empowered to enact identity work to build strong science identities.

KEYWORDS

agency, figured worlds, identity work, positioning, successful girls in science

1 | INTRODUCTION

Girls should be inspired and supported to engage in identity work (taking action and forming relationships) that positively develops their science identity (Calabrese Barton et al., 2013). How girls employ identity work across science-figured worlds (realms of interpretation in multiple contexts) has lasting effects on their academic and career paths (Brotman & Moore, 2008; Dou et al., 2019; Due, 2014; Xie et al., 2015). During their school years before postsecondary education, these figured worlds are often detrimental to girls' science identity development, and there is a considerable amount of research using a deficit perspective to explore girls' experiences (Carlone et al., 2014; Kim et al., 2018; Scantlebury, 2014; Xie et al., 2015). Many science-figured worlds position boys as more fit than girls to be scientists based on natural abilities, despite the lack of scientific evidence for this deleterious bias (Hill et al., 2010). Privileging boys in science occurs when their science identity is encouraged and girls'

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identities are marginalized (Scantlebury, 2014). White boys' science identities are often privileged in seeing the stereotypical scientists as White, middle-aged men who wear lab coats (Ferguson & Lezotte, 2020). These norms from a deficit perspective need to be disrupted so that girls' science identity work is valued and supported in multiple figured worlds.

This study examines the identity work of successful women in science during their school years before post-secondary education using a phenomenological research design. "Successful" is understood as persisting in science and progressing in professional positions. This examination of successful women in science is critical for theoretical and practical reasons. Research has been conducted to develop science identity models (Calabrese Barton et al., 2013; Carlone & Johnson, 2007) because identity has momentary and lifelong implications (Dou et al., 2019; Gonzalez et al., 2020). A theoretical understanding of successful women's identity work adds to the positioning and agency constructs of these models by adding experiences from a non-deficit perspective. From a practical standpoint, Carlone (2017) and Flyvbjerg (2001) argued that understanding science identity helps science educators develop learning experiences that disrupt gender stereotypes in science-figured worlds. The research question that guided this examination was, *What identity work did successful women in science engage in during their pre-collegiate school years?*

2 | CONCEPTUAL FRAMEWORK

2.1 | Identity work, figured worlds, and identity

Calabrese Barton et al. (2013) described identity work as "…actions that individuals take and the relationships they form (and the resources they leverage to do so) at any given moment and as constrained by historically, culturally, and socially legitimized norms, rules, and expectations that operate within the spaces in which such work takes place" (p. 38). Girls engage in positive identity work when they position themselves as science leaders in the classroom and build relationships with others who help them achieve their goals. Calabrese Barton et al.'s (2013) description proposes that identity work occurs within contextualized spaces shaped by historical and cultural social factors, which Holland et al. (1998) coined as "figured worlds." There are dynamics of power, privilege, and marginalization in these spaces. With this understanding of identity work and figured words, identity is seen as a set of behaviors and attitudes that evolves and is influenced by figured worlds—identity changes within figured worlds and at various times in life.

2.2 | Redefining the rules of the science-figured world

The identity work that girls enact occurs within figured worlds that affect their science identity development. Holland et al. (1998) explained figured world is "…a socially and culturally constructed realm of interpretation in which particular characters and actors are recognized, the significance is assigned to certain acts, and particular outcomes are valued over others" (p. 52). The physical classroom, students, and norms in school science contribute to how girls interpret their figured worlds. This could be a space that values girls' contributions and helps them see themselves as scientists. Nature camps and other science contexts are figured worlds contributing to girls' science identity. In multiple science-figured worlds, girls can engage in actions and form relationships that interweave together to contribute to their science identity development (Carlone et al., 2014). Calabrese Barton et al. (2013) examined the experience of a middle school African–American girl, Chantelle, who lived in multiple figured worlds that recognized her contributions and developed her science identity. Throughout fifth grade, she aspired to be a dancer or professional singer. Chantelle attended an after-school community youth center and joined the "Green Club," which focused on energy conservation. Leaders of the "Green Club" valued her work and provided her opportunities to become an expert on conservation matters. Furthermore, the school principal was supportive of her group's work and encouraged her to present methods to conserve energy to the school government. After 3 years, Chantelle wanted to utilize her artistic qualities and scientific knowledge to find new ways to conserve energy. Over those 3 years, community leaders, teachers, and the school principal positively impacted her science identity. They facilitated multiple figured worlds (after-school club and school science) where Chantelle coherently enacted a positive science identity driven by her interests. Opportunities beyond and within the classroom allowed her to build meaningful connections of how science affected her surroundings.

Understanding girls' science identity work through the lens of multiple figured worlds provides analytical power to disrupt the science community's masculine characterization and provide nuance that is important for disrupting gender biases or, in essence, redefining the rules. Understanding science-figured worlds from

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multiple contexts provides perspective into identity development paths that have been shown to improve girls' science identities (Calabrese Barton et al., 2013; Farland-Smith, 2009). In this study, examining the identity work that successful women scientists engaged in during their school years provides insight into how they redefined the rules of the masculine characterization of science. Agency and positioning are conceptual lenses to examine their identity work to disrupt marginalizing implicit rules and norms.

2.3 | Positioning for power and privilege

Identity work can be analyzed by how girls position themselves and others position them within science-figured worlds. Positioning can be defined as the appearance, dialogue, and actions that affect the power and privilege that girls enact within their different figured worlds (Holland et al., 1998). Power and privilege through positioning in the science classroom may be demonstrated by consistently leading laboratory activities and recording data. Boys often are positioned to make decisions about how to conduct scientific investigations and direct the actions of others in groups. Recording data, a task that girls are often expected to take on (Due, 2014), develops organizational skills but not planning and decision-making skills essential to engaging in authentic science experiences. Holland et al. (1998) further operationalized positioning in general contexts.

> The dialect we speak, the degree of formality we adopt in our speech, the deeds we do, the places we go, the emotions we express, and the clothes we wear are treated as social indicators of claims to and identification with social categories and positions of privilege relative to those with whom we are interacting. (p. 127).

There are examples of girls positioning themselves as powerful science students that contradict the deficit perspective. Archer et al. (2017) investigated the experiences of seven high school girls who aspired to pursue a career in physics. Researchers found that participants positioned themselves as intelligent and competitive by aiming to be the top performers in the class. They were confident in their academic abilities and noticed their peers and teachers. Four participants did not describe themselves as feminine or "girly" because they often swore and wore jeans and t-shirts. These girls felt it was essential to behave how they believed scientists conducted themselves versus how femininity is stereotypically demonstrated. In this study, understanding the positioning of successful women during their school years enlightens understanding of how girls gain privilege and power in multiple science-figured worlds.

2.4 | Taking agency to achieve science goals

Agency can be defined as a girl's position, attitude, thoughts, and actions to achieve her goals within science-figured worlds (Basu & Calabrese Barton, 2007; Calabrese Barton & Tan, 2010). Strategic and self-promoting behaviors in science, such as girls positioning themselves as intelligent and competitive, are examples of science agency when these behaviors advance their goals. Moreover, girls may improvise to persist and become successful in science. Improvising, a form of agency, is seeing and acting upon a vision that guides an individual to move beyond her figured world and achieve her goals (Holland et al., 1998). Girls may not have support from their figured worlds but are creative and strategic with their resources to achieve their science goals. Improvising can be seen when girls create their path in science despite the restrictions of their figured worlds. Understanding agentic moves that successful women in science took is important for empowering girls to enact positive science identity work and developing theoretical models.

3 | METHODOLOGY

This qualitative phenomenological study extends a more extensive study exploring women's science identity development in science (Hall, 2018). The phenomenological research paradigm fits the study's purpose of exploring the essence of a phenomenon from the participants' reality (Bevan, 2014; Merleau-Ponty, 1956). In this study, the phenomenon is identity work in science-figured worlds as recalled by successful women in science sharing their realities. The phenomenological research paradigm provided a systematic path for authors to examine and describe the lived experiences of successful women in science by surfacing their experiences and highlighting their voices.

3.1 | Participant selection criteria and recruitment methods

Purposive sampling was used to select participants who met several criteria to be included in the sample. First, all participants were science professionals, which excluded undergraduate or graduate students. Second, the qualifier "successful women" meant that participants had worked in

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TABLE 1 Participants' race and postsecondary educational background

Pseudonym	Ethnicity/ race	Educational background	Career titles
Rachel Carson	White	B.S. Biology and M.S. Environmental Sciences	Manager of City Lakes Department
Barbara McClintock	White	B.S. Biology and M.S. Genetics	University Biology Instructor
Dr. Marie Curie	White	B.S. Physics, M.S. Physics, and Ph.D. Geophysical Sciences	Senior Scientist
Dr. Marie Daly	Black	B.S. Chemistry and Ph.D. Chemistry	University Chemistry Professor
Fanny Hesse	White	B.S. Biology	Safety Professional
Dr. Beatrice Hicks	White	B.S. Chemical Engineering, M.S. Geological Sciences, Ph.D. Environmental and Atmospheric Sciences	Associate Director of Science
Dr. Dorothy Hodgkin	White	B.S. Chemistry and Ph.D. Physical Chemistry	Climate Scientist and Program Director
Dr. Ruth Patrick	White	B.S. Geology, M.S. Environmental Science Master of Public Affairs, and Ph.D. Forestry and Environmental Sciences	Assistant Professor of Environmental Studies
Dr. Lise Meitner	White	B.S. Physics and Ph.D. Physics	Particle Physicist
Margaret Nice	White	B.S. Biological Sciences and M.S. Biological Sciences	Wildlife Ecologist
Dr. Helen Rodríguez Trías	Hispanic	B.S. Chemistry, M.S. Chemistry, and Ph.D. Chemistry	Assistant Professor of Chemistry
Dr. Alice Wilson	White	B.S. Geosciences, M.S. Earth Sciences, and Ph.D. Environmental and Atmospheric Sciences	Research Scientist

a science position for 5 years and had been promoted or had progressed in the tenure process. Third, participants worked in one of the following fields: physical sciences, chemical, earth sciences, or life sciences. The sample included participants who worked in private industries, governmental agencies, and higher education institutions located throughout the United States. Table 1 shows the participants' pseudonyms, race, postsecondary educational backgrounds, and career titles. Participants were recruited through a convenience sample available by a university program the first author led for women in science. Participants were also recruited using the snowball method through recommendations provided by scientists and professionals the first author collaborated with while completing his doctoral studies.

3.2 | Data collection

Participants engaged in three audio-recorded interviews via Zoom or face-to-face meetings. For Zoom interviews, telephone calls were used as a backup when bandwidth interruptions were experienced. They discussed recollections, descriptions, and reflections of their science identity development that followed Seidman's (2006) interview protocol. Each of the three interviews lasted 1.5–2 h, and less than a week was between each meeting. This design helped the first author and participants build rapport and recall recent conversations, facilitating authentic discussions about participants' science experiences. The first interview focused on participants' life history related to science, including their school years. Below are selected questions and prompts asked during this interview:

1. Going as far back as possible, please tell me about yourself prior to becoming a science professional as it relates to science.
2. What was your earliest memory of being interested in science and describe that as much as you can?

The second and third interviews explored participants' science experiences as professionals in the field and reflections on their science identity development, respectively. The three-interview structure allowed the first author to clarify discrepancies in participants' recollections of identity work shared during earlier interviews.

3.3 | Data analysis

Colaizzi (1978) developed a multi-step procedure for data analysis that the first author followed to analyze the data

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descriptively. Each interview was transcribed using online transcribing services and InqScribe software. The transcripts were read to gain a general idea of the participants' experiences. Google Sheets and Microsoft Excel were used to organize the data in the next steps of data analysis. Key descriptions were identified and units of meaning (e.g., early engagement in authentic science, persisting through challenges, taking science leader role) were developed by iterative analysis of the transcripts and the constructs of the conceptual framework (identity work, positioning, and agency). For example, when participants described their engagements in authentic science, their stories were understood through the lens of identity work and figured worlds. The units of meaning were clustered to develop themes, so the theme *"stubbornly" persistent in science-figured worlds* emerged to continue the example. Finally, rich descriptions comprised of themes and verbatim quotes were developed. After the first author completed these steps, the second author offered insights and suggestions.

3.4 | Trustworthiness and positionality

Steps were taken to uphold the trustworthiness of the study and minimize the authors' bias. The three-interview structure (Seidman, 2006) provided time for member-checking by listening to previous interviews and asking follow-up questions. When discrepancies occurred, participants shared contextual details to help the first author understand their stories. Member checking was important to support the trustworthiness of the data because it allowed for a systematic method to verify stories shared by participants (Guba & Lincoln, 1994). Also, long verbatim quotes to exemplify themes were used to support the transparency of the analysis (Creswell, 2013). Given the first author's positionality as a White male in the science education field, reading pertinent literature sensitized him to parts of the participants' stories he had not experienced. The second author, an African American male, was not involved in the data collection and initial data analysis. This approach afforded the second author the opportunity to offer insights beyond those gleaned by the first author.

4 | FINDINGS

Four themes emerged through examining the identity work successful women in science enacted during their pre-collegiate school years. The themes are structured with explanations and quotes to form thick descriptions of participants' identity work. These descriptions of identity work show the positioning and agency that played significant roles in participants' science journeys. Pseudonyms are used throughout the following sections and are names of successful women in science.

4.1 | Theme 1: Early interest in mathematics and science

Early in their elementary years, participants did not recognize themselves as scientists because they did not understand the meaning of being a scientist. They recalled positioning themselves as being interested in how the natural world works. They enjoyed exploring nature and asking their parents questions about their observations. Rachel Carson recalled her curiosity for the natural world when she discussed childhood camping trips with her parents:

> We did a lot of like camping and hiking. Things where…I think he [father] enjoyed teaching us, but [he] did not really think about teaching us. You know? We turned over a rock and ask, 'What kind of bugs are under here? What kind of tree is this? Did you know you can eat this?' Just stuff like that. We spent all kinds of time doing that.

Participants enjoyed learning how the natural world worked and explored this interest during their time with their families. Fanny Hesse recalled her enthusiasm when her father gave her a solar-powered car:

> I remember he [father] would bring home toys, like a solar-powered toy. It was like a little car. And it was right when solar power was getting hot. I thought it was the coolest thing in the world. I'm like, 'This works on energy?' I'm like, 'This is so cool!'

In school, most participants recalled their interest in mathematics and science. They positioned themselves as students who earned positive reinforcement from their peers and teachers partly because of their ability to do well in classes. They earned high grades, most mentioning that they earned straight A's. Participants often discussed their mathematics experiences when asked about science, conveying the inherent connection between the two content areas. As an example, Dr. Patrick explained, "Well, so I was definitely a kid who did well and liked math and liked science in school. Like even in elementary school." Dr. Rodríguez-Trías discussed that mathematics and science information was logical. Here she shared:

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> But I think it's easy to become better at math because you learn the smaller stuff and then you can do so many things with that. So, I think I was good at math, good at science, and it was easy to get an "A."

During their school years, participants recalled feeling satisfied knowing there was a correct answer to solving math problems and seeing how science was practical for many of their homelives. Dr. Wilson's family had a farm, so she helped with tasks and had many conversations about the weather as a young girl. Understanding the weather was necessary because their livelihood depended on raising crops and science conversations with her family could answer her questions. Here she explained:

> I was more like very factual with what's happening on the farm. What's the weather like… I mean, I was just growing up being very concrete about life, and not necessarily spending as much time philosophizing about where our nation was at, or the world was at.

Dr. Wilson characterized herself as "factual" in the context of learning the environmental components important for farming. McComas et al. (2002) discussed the importance of understanding the tentativeness of scientific knowledge, which is different from stagnant facts, and processes of science that develop knowledge. Dr. Wilson discussed the process she engaged in to develop scientific knowledge in *Theme 3—Engagement in Science Figured Worlds Beyond School*. As young girls, participants valued learning practical knowledge and often were situated in science-figured worlds with opportunities to learn what could be applied to their inquiries.

4.2 | Theme 2: "Stubbornly" persistent in science-figured worlds

Participants often used the term "stubborn" when describing their persistent identity work to achieve their science goals. Dr. Meitner reflected on her identity work as she was determined to achieve her childhood goal of earning a Ph.D. in science, "I was very stubborn. I couldn't imagine what else I would do." They acknowledged struggles yet continued to position themselves as students interested in mathematics and science. For many participants, their challenges were beyond their control and they engaged in improvisational identity work. Dr. Wilson had dyslexia and struggled to participate in everyday activities in elementary school. She was aware that some teachers held implicit biases about her learning abilities, which were detrimental to her identity as a student. They did not position her as a student who could achieve success in school. However, she engaged in several forms of agentic identity work that helped achieve her science goals. She learned study strategies that helped her resolve issues symptomatic of dyslexia by working with her parents and supportive teachers. This identity work allowed her to become a successful student who grew to love learning despite her challenges. Here she reflected on this transition:

> So, I went from being very traumatized as a first-grader with my dyslexia to just loving to learn and loving to find ways that would work with me to achieve new knowledge. And just discover, you know, what areas would resonate with my thirst of knowledge.

She was agentic in academic and social challenges associated with dyslexia to gain new knowledge. Moreover, she used this experience to focus on mathematics and science as she recalled being gifted in these areas.

Dr. Rodríguez-Trías' and Barbara McClintock faced problems in low-income families and communities. Dr. Rodríguez-Trías' high school teachers did not expect most of her high school peers to attend college. School counselors only discussed college with students at the top of the class. Here she explained:

> In the school, because we were coming from poor communities… So, they kind of… I was suggested to go to technical school, not necessarily college. But I always tried to study so hard. I was one of the best. Like maybe ranked first or the second one [in her class]. So, the few people that were very high, they [school counselors and teachers] talked about college. So, they kind of gave you some insight into that. So, they talked to me about college.

Dr. Rodríguez-Trías' improvisational identity work included active engagement in her academics which helped her become a top-performing student of her high school class. Her identity work prompted her high school counselor to recognize her as a future college student. The school was Barbara McClintock's "happy place," especially her science courses. She perceived academic success as a solution to her troubles at home. She described:

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> My mother and I were living in really hard neighborhoods. I was around people that did not value education in my neighborhoods. And so, I was internally motivated. And, at one point, stuff got so crazy that I moved out of my house. I was under-aged. I was living with friends. And I was riding my bicycle, back and forth to school every day, not to miss school because education was going to be my way out of everything.

Participants also faced implicit biases based on gender beliefs. Dr. Patrick recalled the low enrollment percentages of girls in her high school physics courses and her physics teacher did not ask girls questions:

> So, I was in advanced physics or whatever. I think there were three girls and 17 boys in the class. And then, the other regular physics classes only had an additional four women. And, and in our grade, it was two-thirds women, right? So, all the guys took it and only like six people, six women took it. And three of us were in the advanced section. We never got called on and we sat in front.

Her physics teacher's pattern of gender-biased behavior prompted her to engage in agentic identity work by submitting a formal complaint. Her complaint prompted a conversation with her high school's fairness committee. She recalls her physics teacher claiming to be unaware of his gender-biased actions. Dr. Meitner performed agentic identity work by earning her associate's degree in high school. However, went she set forth to accomplish this goal, her guidance counselor was not encouraging. She described how interactions with her guidance counselor motivated her to prove him wrong:

> So, I started out my junior year of high school wanting to do that [earn her associate's degree], but I didn't take very many college classes to begin with and my counselor at the high school looked at what I had done so far and what I had left to do, and he was like, 'You're never gonna make it. You're never going to get your associate's degree. There's just too many things.' And I was like, 'Well, I can't accept that.' And so, my senior year, I took 21 credits for three terms to get my associate's degree because I was like, 'I'm going to do this.' So, I was the first girl at my high school and the third student period to make it through that program with an associate of science when I graduated high school. So, it was more the fact that he told me I couldn't do it than it was anybody cheerleading me on saying that, 'Yeah, you can totally do it.'

She was "stubbornly" persistent in taking agentic identity work and preparing herself for a science degree in college. She used discouraging advice to serve as motivation to accomplish her science goals. Participants engaged in agentic and improvisational identity work by overcoming social and academic challenges.

4.3 | Theme 3: Engagement in science-figured worlds beyond school

Participants engaged in science experiences outside the classroom, such as family activities, science fairs, and outdoor camps. These figured worlds offered participants opportunities to ask meaningful questions and investigate them. They positioned themselves to engage in personally meaningful science identity work. As discussed earlier, Dr. Wilson's parents were farmers, so understanding plant growth factors affected their livelihood. She engaged in science positive identity work by asking questions and designing an experiment derived from her family's garden experiences. Here she explained:

> When you seed carrots, at some point, you have to pull some out, because they're many, right? I'm like, 'What a waste, Dad. You have all these beautiful baby carrots that you're just pulling out.' Okay, it is to make bigger carrots. But I'm like, 'I'm going to try to plant these baby carrots again in some little corner of the field.' And he's like, 'It's not going to work.' Even though he was.... He taught biology, and he knew science. He was like, 'No, it's not going to work. It's not worth your time.' And for him, his view is that he wanted huge carrots to grow. But for me, I wanted to know if that little baby carrot is going to become a medium carrot or is it dead when you pull it out. So, I planted 10 in my little corner, and I told my Dad, 'Don't pull them. Just leave them. I'm going to water them and see if I get [medium carrots].' And they grew. I was, 'Look at that, Dad! I have bigger carrots.'

Dr. Wilson was concerned about wasting carrots and she positioned herself to collect evidence to have a

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scientific argument with her Dad. She designed an experiment to collect evidence to show her Dad that small carrots could be used and was excited to show him that her investigation could lead to more responsible gardening. Margret Nice also grew up in an agricultural-figured world and appreciated how science was used to care for farm animals. During high school, she engaged in agentic identity work by interning for a veterinarian. She recalled:

> He [the veterinarian she interned for] was one of those vets that goes around to the farms and works on the cows and pigs and horses and stuff. And he had an office too so I worked, I worked with him. He'd take me around places and do stuff and that was fun.

Dr. Marie Daly was excited to learn about forensic science and took improvisational steps to pursue this career outside of school. Forensic science was not a well-known field when she learned about it and her mother did not believe it was plausible. Here she explained:

> I can solve murder mysteries. I can use science to do it and I can help people because I liked helping people at that time. This is the one career! Like bam, this is it! This is all I what. And I told my mom about that and she was like, 'Nobody can do that.' And I was like, 'Yeah they can.' And from there I just tried to find every forensic science relevant book and I followed it. I did my own research because nobody really knew about it.

Dr. Dorothy Hodgkin described a similar experience with science fairs during high school:

> I didn't have much money. I was in a public high school so my teacher didn't have much money for supplies. But figuring out how I can do this [science fair project] with the resources that I have that are just in the typical high school chemistry lab. Then kind of seeing some other things that other students were doing and thinking, wow, look what else you can do if you have additional resources! And so I think, that did make me... That was the first time when I felt like experiments are really cool!

Experiencing how questions could be answered from a scientific perspective at a science fair was intriguing and encouraged agentic steps to pursue a career in science.

From ages eight to 21, Dr. Patrick was a camper in an outdoor camp and eventually became a counselor. Her identity work in this space involved nature identification with other campers and counselors. As she reflected on this experience, the concept of identity was discussed, "But, I think it was really helpful because I went away every summer and I like sort of got this like rejuvenation of my identity that I was inside." This space was rejuvenating to her school experience that was not always supportive of her interests in science. She continued, "Like I think that summer experience helped me be more resilient during the rest of the year when I was, maybe, teased or whatever." Dr. Patrick's camping experience was a figured world that valued her science identity. This space energized her to disrupt gender norms in her science-figured world at school, which included low enrollment of girls in physics courses and an instructor who did not include girls in classroom discussions, as explained in their previous section. Science-figured worlds beyond school experiences were meaningful for participants to engage in positive identity work.

4.4 | Theme 4: Positioning themselves as science leaders

Several participants took agency by leading their peers in science experiences during their school years. Their curiosity for science, persistence through struggles, and science experiences beyond school helped them take these science leadership roles. Leadership can be defined as the ability to lead through determination, confidence, and self-discipline. In elementary and high school, Dr. Rodríguez-Trías held a strong work ethic motivated by an appreciation for her parents' support in pursuing academics. She positioned herself as a group leader through her determination and academic talents. As she described, "I led groups. Yes, in elementary school, middle school. So, I always was the leader of my groups." Dr. Marie Curie described leading groups with her intelligence in high school:

> People [her high school classmates] were happy to study with me because I could hold my own. But I also, I led with my intelligence. I didn't lead with the idea, I'm a cute girl and can you help me or anything.

When recalling her earliest science memory, Dr. Beatrice Hicks explained enjoying individual work completed at third-grade science stations. She explained:

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> So, you would go and pick out the sheet and it would have the instructions on what to do. You went over to your station and you had to do them. You could work at your own speed and they didn't make me have a partner. So, I didn't have anyone bothering me.

She described feeling excited in science class because each problem was different and she appreciated the responsibility of completing her work. She positioned herself as a leader in science early by enacting self-discipline and determination at a young age to complete her work.

During her senior year of high school, Dr. Patrick served as an intern at a local hospital for the biomedical lab. In this experience, she built relationships with nurses and doctors and learned that women were paid less than men. Her high school experiences (notably with her physics teacher, as explained in the previous section) and as an intern focused her attention on equity issues in science. These experiences led her to present equity in science during her senior presentation. Here she described her mother's recollections of her presentation:

> And then, she's [her mother] like, you essentially like stood up taller and she's like, it.... She said it was like the first time she saw me on sort of soapbox, right? Like I just got really impassioned in talking about how women in science are not treated fairly.

Her confidence and determination display her agentic identity work as a leader in high school. All participants took agency in achieving their science goals through acts of leadership, despite the challenges embedded in implicit gender biases of their science-figured worlds.

5 | DISCUSSION

The ongoing deleterious phenomenon of gender biases that marginalize girls' experiences in science needs to be disrupted. Educational systems have the opportunity to focus on intentional efforts to redefine the rules of science-figured worlds that facilitate girls' positive science identity work. This work is meaningful because girls who engage in positive identity work during their school years are more likely to see themselves as scientists than those who do not (Calabrese Barton et al., 2013; Kang et al., 2019). The recollections from 12 successful women of their science identity work examined in this study add to the science identity models from a non-deficit perspective (Carlone & Johnson, 2007) and provide practical guidance on disrupting gender biases.

From a theoretical perspective, Carlone and Johnson's (2007) science identity model highlights the importance of girls positioning themselves as scientists. The participants' recollections in this study add to this model by providing specific enactments of positioning and agentic identity work. The identity work of participants in the current study started with their early positioning of interest for science within interweaving science-figured worlds (school, beyond school, family). During their elementary years, their interest in science and mathematics drove their agentic and improvisational identity work (being "stubbornly" persistent in science and taking leadership roles in science) that positively developed their science identity. This enactment can be seen in Dr. Rodríguez-Trías' recollections in her dedication to doing well in science despite a science-figured world based on "realistic" expectations for an underprivileged community (teachers and counselors did not expect students to pursue college). Girls interested in science and engaging in agentic identity work disrupt the deficit perspective often embedded in gender essentialist thinking. This perspective suggests that boys and girls naturally have different interests and skills and there is a belief that girls are not "naturally" interested in science (Due, 2014; Scantlebury, 1995; Weinburgh, 1995), which negatively affects girls' access to science opportunities (Alexander et al., 2012). Science educators can disrupt this assumption by facilitating science-figured worlds that allow girls to develop their interest in the natural world.

Understanding the identity work of successful women science through an identity work conceptual framework informs several practical lessons. This study's findings, along with other studies examining girls' positive identity work (Archer et al., 2012; Archer et al., 2017; Calabrese Barton et al., 2013), can inform the development of science pedagogies and curriculums from a feminist perspective. From an early age, girls should engage in science experiences that support their interest in science. Participants had authentic science experiences that developed their interests and allowed them to practice science skills. For example, Dr. Wilson designed an experiment to investigate her father's assumption that small carrots removed from the ground could not be replanted to increase in size. The findings from this study and previous studies show that girls value autonomy in their scientific work, which often is connected to supporting their communities and environments (Calabrese Barton et al., 2013; Hill et al., 2010). These experiences should facilitate girls' exploration into questions relevant to their

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interests and have a meaningful societal, familial, and environmental impact (Wieselmann et al., 2020). Science educators and school administrators should disrupt gender-biased norms in science-figured worlds by collaborating with caregivers and family members to facilitate these meaningful science experiences for girls. As shown by participants' recollections, these interweaving science-figured worlds offered opportunities that could be aligned to develop girls' science identities positively.

The participants' "stubborn" characterization of their agentic identity work should pause science educators and researchers to reflect on how girls see themselves in science. Girls' agentic identity work characterized as "stubborn" has a negative connotation and is nested in documented double-blind circumstances (Hill et al., 2010). Girls need to consider their science-figured worlds' interpretation of femininity, gender-normed behaviors, and acceptable actors when performing science identity work. In one case, Archer et al. (2017) found that high school girls who aspired to continue to postsecondary physics programs needed to decide whether they would be "girly" or scientists. The recollections of successful women add to the science education research literature by sharing how participants successfully navigated double-blind circumstances throughout their pre-collegiate years. To take on science leadership roles during their school years, participants "stubbornly" disrupted the rules of some of their science-figured worlds. Dr. Patrick did this when she raised attention to her high physics teacher's unconscious avoidance of asking girls questions. Participants' science identity work was valued and supported in some of their figured worlds. These spaces allowed them to participate in scientific inquiry to answer personally meaningful questions. In turn, these experiences also motivated them to excel in science and take leadership positions. Participants felt empowered to show their whole science identity in these spaces, as seen by the rejuvenation of Dr. Patrick's science identity through her identity work at a nature camp over several summers. Science educators and researchers should partner with girls in performing identity work that disrupts gender-biased norms in their science-figured worlds. These efforts could help shift a "stubborn" perspective to agentic science identity work. Recognizing and developing girls' interest in science requires intentional action because of the implicit gender biases in science-figured worlds (Scantlebury, 2014). Science educators, school administrators, and researchers are responsible for disrupting gender biases so that girls can enact positive science identity work and this process can begin with understanding implicit biases. Engagement in ongoing self-examination using tools such as the Gender-Science Task implicit association test (Implicit, 2011) can surface implicit biases. Reflection and discussion may grow awareness of this issue and could serve as an impetus to facilitating science pedagogies and curriculums from a feminist perspective.

There are some limitations to the current study that support the need for more examinations of successful women in science. Given that the majority of the participants are White, the study is biased toward the identity development of White girls and women. Future studies should examine majority non-White samples to deepen understanding of identity development constructs. Also, participants were asked to recall their experiences from childhood which introduces the possibility that participants reconstructed their recollections based on more recent experiences and beliefs. Future studies should provide girls opportunities to describe their current experiences as they employ identity work in science-figured worlds. Finally, the data analyses were limited to male perspectives. Future studies should include women in these procedures to mitigate gender biases.

6 | CONCLUSION

Calabrese Barton et al. (2013) suggested, "Identity is a powerful construct for understanding student learning because identities are constructed through practice—practice that requires knowledge, skills, and ways of thinking that characterize the discipline in which one is engaging" (p. 41). This study explores how successful women scientists engaged in science identity work and surfaced salient aspects that affected their science identity development. They recalled positioning themselves as interested in the natural world through curious identity work that developed into a passion for science. This positioning drove their agentic identity work that grew through their school years in interweaving figured worlds. Understanding their identity work is helpful for students, parents, teachers, administrators, and researchers in structuring figured worlds of science to support girls' positive science identity development. Science educators can use the knowledge gained from this study to implement pedagogies and curriculums that facilitate figured worlds that support girls' positive identity work. Also, girls could employ the agentic identity work that participants used to develop their science identity. Science educators and researchers are encouraged to focus on learning how to structure figured worlds where girls feel empowered to enact identity work to build strong science identities.

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