



## RESEARCH REPORT

# A comic-based conservation lesson plan diversifies middle school student conceptions of scientists

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### Abstract

Role model interventions that are tied to place based-learning and classroom curricula may be effective tools for promoting diversity in STEM. To evaluate this premise, we developed a sixth-grade lesson plan that focused on teaching environmental conservation and highlighting diverse women in science. Our curricula used a three-touch educational model consisting of comic-based lesson plans, a local “field trip” to Cabrillo National Monument, trading cards featuring 19 diverse women scientists, and a conservation capstone poster presentation - all aligned to Next Generation Science Standards - to create a meaningful experiential and project-based module. To evaluate the program, we used a mixed-methods, change over time model, including the Draw-a-Scientist test (DAST) to assess if student perceptions of scientists were altered from the curricula. Overall, thirty-three students completed the DAST before and after participation, and we found that science stereotypes held by students decreased after participation in the lesson plan. By using innovative tools such as art and comics for science education/outreach that feature characters representing a diverse array of scientists with intersectional identities, educators can help shift student perceptions on who can be a scientist, potentially increasing diversity in scientific fields.

**Keywords:** Draw-a-scientist, middle school, biology, place-based learning, scientist stereotypes

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Recent reports have reinvigorated prioritizing equitable K-16 science, technology, engineering, and mathematics (STEM) education (National Academies of Sciences, Engineering and Medicine, 2021). STEM education is considered critical for promoting inquiry, innovation, and lifelong learning (Tanenbaum et al., 2016). Encouraging young students to pursue STEM careers is necessary to meet increased demands in the STEM labor workforce (President's Council of Advisors on Science and Technology, 2012), to meet the unique scientific challenges of the 21st century, and to ensure that all students have opportunities to succeed in STEM fields (AAAS, 2011). Increased representation of historically marginalized groups provides one avenue of meeting increased workforce needs of STEM talent. Representation and inclusion of historically marginalized individuals in the STEM workforce is a matter of equity and social justice (Briggs, 2017; Geesa et al., 2021).

While representation of women and historically excluded individuals (Black or African Americans, Hispanics or Latinos, and American Indians or Alaska Natives) in STEM has increased in recent years, inequities still exist in a number of fields (NCSES, 2021). For example, while biology is typically noted as reaching gender parity, subfields such as ecology and evolutionary biology are notable for their lack of inclusion of individuals with underserved ethnic backgrounds, particularly those holding intersectional identities (NSF, 2018). There are a myriad of reasons for this sustained lack of diversity, including historical exclusion from STEM fields and current challenges to inclusion and sense of belonging (O'Brien et al., 2020). One important aspect of increasing the number of women and historically excluded individuals in STEM careers is by encouraging students at early ages to pursue interests in these sectors.

#### *Student interest in STEM*

Students' conceptions of scientists and perceptions of scientific careers are solidified during elementary and middle school, and may have impacts on their long-term interest and retention in STEM (Buldu, 2006; Mohtar et al., 2019; Wyss et al., 2012). Indeed, student interest in STEM by the start of high school is a predictor for their interest at the end of high school (Sadler et al., 2012), and eighth grade students who expect to have careers in the life sciences are 1.9 times more likely than their peers to earn life sciences baccalaureate degrees (Tai et al., 2006). However, middle school students hold limited knowledge about the diversity of careers in STEM (Blotnicky et al., 2018). A review of STEM education in primary school found that children are engaged in STEM learning, but that a number of barriers including lack of time or professional development make it challenging for teachers to incorporate in the classroom (Wan et al., 2021). Studies of children indicate that student interest in STEM increased if the students were male, came from higher socio-economic backgrounds, had prior achievement in reading and numeracy, and if they had a parent with a job in STEM (DeWitt et al., 2013; Holmes et al., 2018). School is a place where all students can access information about STEM careers, which is critical for students who do not

have family members working in STEM occupations. As students' interest in STEM can increase when provided with information about STEM careers (Wyss et al., 2012), middle school becomes a critical period for attracting students to STEM.

### *Representation of STEM and the Draw-a-Scientist Test*

Middle school is also a key time for fostering interest among diverse students, and for addressing gender stereotypes about scientists. There is a wealth of literature exploring gender stereotypes (of people of all ages) and scientists, but particular focus is given to secondary students and when stereotypes are formed.

In 1957, researchers Mead and Metraux conducted an analysis of secondary school students' responses to a prompt asking them about what they think of when they think of scientists. Through this research, the authors identified the stereotype of the scientist as an old white man wearing a white coat, glasses, and working in a laboratory surrounded by equipment such as glassware, microscopes, and chemicals in test tubes (Mead & Métraux, 1957). In order to explore when these stereotypes of scientists emerge in children's thinking, subsequent researchers developed the Draw-a-Scientist Test (DAST) where students are asked to "draw a picture of a scientist" (Chambers, 1983). Researchers selected seven stereotypical indicators of scientists, and coded for the presence/absence of each category. In their analysis of student drawings, the researchers coded for: 1) lab coats, 2) eyeglasses, 3) facial hair, 4) symbols of research, including scientific instruments and lab equipment, 5) symbols of knowledge, primarily books, 6) technology, and 7) relevant captions such as formulae or taxonomic classifications (Chambers, 1983). In their analyses, the presence of multiple types of categories (for example, two scientists with eyeglasses) would be coded as one indicator (eyeglasses).

Subsequent studies have modified the DAST tool, adding rubrics and questionnaires to further quantify and probe student perceptions (Farland-Smith, 2012; Finson et al., 1995; McCann & Marek, 2016). For example, the DAST-C created a checklist of the seven indicators from Chambers (1983) and added an additional eighth element: alternative images, which was comprised of eight other items including: if the drawing included a white male older scientist, had indications of danger or secrecy, lightbulbs, included work conducted indoors, or included mythic stereotypes such as Frankenstein creatures or "mad" scientists (Finson et al., 1995). More recently, Farland-Smith (2012) developed a rubric scoring drawings and follow-up questions collecting richer details from the students themselves regarding their drawn scientists' appearance, the location of work, and scientists' activities.

Overall, decades of research using DAST have revealed that children consistently and overwhelmingly stereotype scientists as men (Ferguson & Lezotte, 2020; Miller et al., 2018). A meta-analysis of 79 published studies that used the DAST over the past 50 years revealed that while there has been an overall decrease in gender stereotyped drawings, students of different

genders and ages have decreased in their stereotypes held at different rates, with girls on average drawing 58% of scientists as men and boys drawing 96% of scientists as men. The researchers also found age effects, where girls between the ages of 10 and 11 switch to draw more male scientists. Similarly, a separate meta-analysis of 30 studies that used the DAST-C published between 2003-2018 found that the most consistent stereotypes and perceptions of scientists included symbols of research (scientific instruments and lab equipment) and male scientists (Ferguson & Lezotte, 2020). However, direct use of the DAST-C rubric poses a challenge in that some stereotypes such as “secrecy” and “light bulb” symbols may be outdated (Ferguson & Lezotte, 2020), and unrecognizable gender identities in drawings pose challenges for interpreting student drawings (Losh et al., 2008). Overall, while the DAST has numerous advantages such as being a quick tool that is easily administered, researchers are limited in the amount of information that can be collected from drawings (Reinisch et al., 2017). To address these limitations, the use of questionnaires to accompany student drawings allows for greater incorporation of student voice in coding drawings (Farland-Smith, 2012).

#### *Conceptual framework*

Our research was informed by the Gender Schema Theory, which posits that children use observations of their environments to associate genders, in particular maleness and femaleness, with attributes (Bem, 1981). This theory has been used as a framework to explore a range of research topics, including stereotyping (Starr & Zurbriggen, 2017). According to Gender Schema Theory, children receive information from their social environments, and organize the information into their beliefs, attitudes, and preferences (Liben & Signorella, 1993). The observations children make result in stereotypes that influence their behavior and decisions well into adulthood (Martin et al., 2002; Steinke & Long, 1996). Family, teachers and peers at school, and the media all influence how children learn sex-role behavior. For example, exposure to TV clips depicting stereotypical female roles (clips of preteen girls discussing boys, clothes, and fairy godmothers) activated stereotypes, and resulted in elementary school girls reporting higher interest in stereotypical career paths such as being a teacher, florist, or stay at home parent (Bond, 2016). Role model interventions typically aim to expose students to counter stereotypical role models, and are generally viewed as a successful means to reduce gender stereotyping in early childhood (Halpern et al., 2007; Olsson & Martiny, 2018), and increase the sense of belonging for girls, women, and racial minority groups in STEM (Casad et al., 2018). As gender stereotypes are linked with interest in STEM (Barth & Masters, 2020), decreasing stereotypes is a priority for increasing girls’ interest and persistence in STEM.

The effects of representation on STEM interest are most notably documented by the “Scully Effect”, which witnessed an uptick in female scientists due to the fictional TV character Dana Scully from ‘The X-Files’ (Geena Davis Institute on Gender in Media, 2018). For many young

girls, Dana Scully was their first indication that a career in STEM was possible. Collectively, this suggests that who is represented as a scientist is greatly linked with who will be encouraged to become a scientist in the future.

### *This study*

In order to shift student stereotypes, STEM role model interventions typically feature real-life STEM professionals who represent diverse backgrounds (Farland-Smith, 2012; O'Brien et al., 2016; Schinske et al., 2016; Steinke et al., 2021). The classroom intervention used in this study was informed by Lent et al., (1994) Social Cognitive Career Theory (SCCT), which describes relationships between students' career-related goals and behaviors and factors such as student self-efficacy, outcome expectations, and interests. Additionally, the model posits that personal characteristics, background factors, and learning experiences influence career choices and has been used to frame numerous informal and formal educational interventions (McDonough et al., 2021).

In order to provide learning experiences that connected content to the real world and provided representation of living scientists, we developed two comic-based lesson plans. Comic-based lesson plans have been shown to be an effective teaching tool for complex biological concepts (Hosler & Boomer, 2011; Norton, 2003; Spiegel et al., 2013). Through creating, STEM comics can aid in new concept retention (Hosler & Boomer, 2011; Quillin & Thomas, 2015) as well as help reveal misconceptions in the material. Through reading, STEM comics not only engage both verbal and visual learners, but also have the potential to highlight the diversity of people behind the science. Additionally, in order to provide role models, we developed 19 trading cards featuring diverse real-life women in science, with careers spanning fields in biology and climate science. Finally, the lesson plans included a virtual poster session where students presented research on a species of their choice and made conservation recommendations. These sessions were moderated by 16 women in STEM. Student research and creation of posters is in line with problem-based learning pedagogy in science, technology, engineering, art and mathematics (STEAM) lesson plans, which in turn fosters student innovation and curiosity (Quigley & Herro, 2016). Thus by shifting teaching these science lessons to STEAM via the inclusion of art, our comics and trading cards aimed to allow a broader spectrum of students to envision themselves as scientists and carry that interest forward in their lives.

This case study represents analysis of data after implementing the *In Their Eyes* lesson plan. We hypothesized that exposure to a diverse array of female scientists would impact middle school students' drawings of scientists.

## Methods

### *Module team*

Our team included a science educator at Cabrillo National Monument, a science illustrator, and an education researcher. We consulted with two middle school teachers to ensure that the materials were age-appropriate and consistent with Next Generation Science Standards (NGSS). Collectively, we aimed to develop a module that would use art (in the form of comic books and trading cards) to teach biological concepts aligned with the NGSS. The module is available at <https://www.nps.gov/cabr/learn/kidsyouth/ite.htm>. Specific NGSS standards addressed are outlined in Table 1. An additional goal was to impact student perceptions of scientists through exposure to real-world role models.

Table 1.

*Next Generation Science Standards addressed in project.*

<b>Learning Objective</b>	<b>Details</b>
<b>From Molecules to Organisms: Structures and Processes</b>	
<b>MS-LS1-4</b>	Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants, respectively
<b>MS-LS1-5</b>	Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms
<b>Ecosystems: Interactions, Energy, and Dynamics</b>	
<b>MS-LS2-1</b>	Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem
<b>MS-LS2-2</b>	Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems
<b>MS-LS2-4</b>	Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations
<b>MS-LS2-5</b>	Evaluate competing design solutions for maintaining biodiversity and ecosystem services

*Note.* MS-LS denotes middle school life science standards

### *Module overview*

The *In Their Eyes* conservation and comics module consisted of a three-touch model including 1) interactive lessons in the classroom, 2) a science education field trip to Cabrillo National Monument, and 3) a scientific poster showing for friends, family, and the public.

The classroom lessons were designed to take place over a minimum of four class periods. During the first class period, students completed a modified version of the Draw-a-Scientist test (mDAST) following instructions outlined in Farland-Smith (2012). In the mDAST, students were

asked a series of open-ended questions: “I am a boy/girl; was the scientist you drew a man or woman; was the scientist working outdoors or indoors; what was the scientist doing in your picture?” We further modified these questions by using open-ended questions for gender, including a question about the drawn scientists’ age, and adding an additional question asking about the inspiration behind why students selected their scientist that they drew (Table 2). Students then began the lesson by playing a Quick-Draw vocabulary game, reading a comic book (focused either on Shaw’s *Agave*, *Agave shawii*, or Belding’s Orange-throated Whiptail, *Aspidoscelis hyperythra beldingi*) with a crossword activity to reinforce vocabulary, and received a packet of 6 trading cards each, from a pool of 19 scientist trading cards. Each trading card included a drawing of the woman scientist on the front with their name and job title, and on the back a short (1-2 sentence) description of their work and hobbies (Figure 1). Fourteen of the scientists featured on the trading cards identified as biologists, and seven identified as working on climate change research or conservation (five scientists identified as both biologists and either climate change researchers or conservationists). The comic books’ protagonists were two biologists who were also featured among the trading cards. Students were encouraged to trade cards, and were informed that two of the cards included scientists highlighted in the comic books and that the other cards featured scientists that they would be meeting during both the virtual field trip as well as virtual poster-session. The scientists featured on the cards were selected due to the type of research they conducted with a focus on scientists a) with research that could be applicable to ecosystems at Cabrillo National Monument, b) with a tie to the If/Then Ambassador program in order for teachers to have access to additional free classroom materials and c) with diversity in age, racial/ethnic identification, and identifying as a woman in STEM.

During the second class period, students participated in a virtual field trip to Cabrillo National Monument, where they learned about the ecosystems and organisms highlighted in their comic books. During the third class period (this period was extended over several days), students worked in pairs to create a scientific poster that communicated local conservation science by selecting a native focal species, threats, and helpful conservation actions. They presented these posters during a virtual poster-session attended by their friends and family as well as 16 women scientists, including 8 who were highlighted on their trading cards (including co-authors SW, JCG, and CLM). Each scientist moderated a breakout room with four student presenters, giving students time to interact individually with a scientist. Finally, students concluded the module by again completing the Draw-a-Scientist test. Students completed the program during hybrid instruction (due to the COVID-19 pandemic), and the module was designed to support virtual as well as in-person instruction. In order to ease participation for teachers, we created an orientation video reviewing a teacher packet of instructions (disseminated to teachers in hard copy and electronic formats).

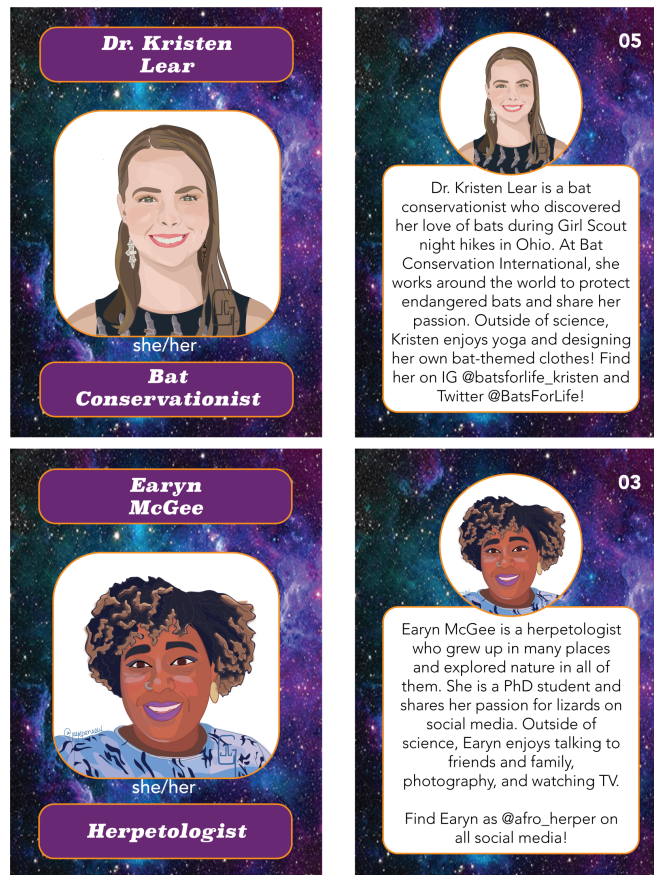


Figure 1. Two example trading cards. Each card depicts a scientist and includes a description of their work and personal interests.

### Participants

Participants were 6th grade students who were enrolled in four classrooms at a Title I school on the west coast that used the “*In Their Eyes*” conservation and comics lesson plans during Spring 2021. Total classroom enrollment was 112 students.

### Data collection

This research was approved by an Institutional Review Board: University of California, San Diego protocol #202009SX. We used a one-group pretest-posttest design in order to maximize our limited sample size and for ease of implementation for teachers during hybrid instruction.

Of the 112 enrolled students who participated in the module, a subset of students filled out a pre- (92 students) and post- (94 students) intervention survey. Prior to the start of the program we collected parental consent, and during each round of data collection we collected student assent. We removed students from the research study whose parents did not consent to share their children’s responses for research, and who did not assent to share their responses for research. If students withdrew their assent to share responses for research, we removed their

drawings and responses from the study. After this process, we kept 36 students who had completed the Draw-a-Scientist test prior to implementation of the *In Their Eyes* lesson plan in April 2021, and 36 students after implementation of the program in June 2021. Of these students, 33 students completed both the pre- and post- drawings. Students were provided a prompt for the Draw-a-Scientist activity and responded to a series of questions about their drawings (Table 2).

Table 2.

*Draw-a-Scientist activity instructions*

<b>Instructions:</b>	Imagine that tomorrow you are going on a trip (anywhere) to visit a scientist in a place where the scientist is working right now. In the space below, draw the scientist busy with the work this scientist does. Add a caption, which tells what this scientist might be saying to you about the work you are watching the scientist do. Do not draw yourself or your teacher and do not use the internet or other resources to help you draw your scientist. After you have created your drawing and colored it, upload a photo of your drawing to the box below. You may use plain white paper and the colored pencils (from your supply bag), or a digital drawing tool if you prefer. When you are done, answer the questions on page 2.
<b>Caption:</b>	What is the scientist saying to you about the work you are watching the scientist do?
<b>Open-response questions:</b>	<p>What is the gender of the scientist you drew?</p> <p>Was the scientist you drew working outdoors or indoors?</p> <p>Was the scientist you drew old or young?</p> <p>What was the scientist doing in your picture?</p> <p>Why did you select this scientist to draw?</p> <p>Is there anything else you would like to share about your scientist drawing?</p>

The inclusion of questions allowed students to share aspects of their scientists' identities, details about what the scientists were doing and their motivations for their drawings. While previous DAST analyses made assumptions about scientists' gender (Losh et al., 2008), by directly asking students we were able to minimize using stereotypical attributes to assign gender during the coding process.

We asked students a voluntary open-ended question "Which gender identity do you most identify with?", and a closed-ended question asking students to identify their race/ethnicity. Self-report demographic identification is included in Table 3. According to USnews, the school's demographics include 67% minority students, 48% female students, and 52% male students. Our dataset includes 16 (57%) students from racial/ethnic backgrounds traditionally underrepresented in STEM, which may be an underestimate of the larger classroom population.

Table 3.

*Student self-report demographics from students who completed both the pre- and post- drawings.*

Demographic variable	Number of students
<b>Gender</b>	
Male	13
Female	12
Other/non-binary	1
No gender reported	7
<b>Total</b>	<b>33</b>
<b>Race/ethnicity</b>	
American Indian or Alaska Native, or other Indigenous group.	1
Asian or Asian American	3
White	11
Hispanic or Latinx	15
Other or prefer not to answer	3
<b>Total</b>	<b>33</b>

#### *Data analysis*

We used the ggaluvial package (Brunson & Read, 2020) in RStudio to construct Sankey diagrams visualizing patterns in student conceptions of scientists, and the Fisher's Exact Test function in RStudio to evaluate contingency tables and test for significance in the distribution of scientist genders drawn in the pre- and post- drawings. We used the effsize package (Torchiano, 2020) to calculate the effect size (Cohen's D) for student stereotype scale scores in the pre- and post- drawings.

Although there are coding schemes for the Draw-a-Scientist test, coding schemes such as the DAST-C are known to be limited in scope and are critiqued as being outdated (Ferguson & Lezotte, 2020). We sought to use students' drawings themselves to inform our analyses in order to capture more information while coding. Additionally, we included student responses to a series of questions (Table 2) during our coding process. First, we coded student descriptions of the gender of the scientists drawn, the location of work of the scientist, and the scientist's age. The three remaining questions and figure caption asked students about what the scientists were doing, why they selected their scientists to draw, and if they had any additional information they wanted to include. We used a grounded theory approach while coding drawings and student responses to these prompts in order to identify emergent themes (Strauss & Corbin, 1990). First, we reviewed the drawings for concepts that were repeatedly present. Three co-authors (CLM, JH, and SN) used inductive coding to develop a codebook based on these concepts to characterize the drawings. In order to test the codebook, the coders independently coded 32 student drawings and responses and compared results while discussing any differences. This process was done

iteratively until the average Fleiss's Kappa score for intercoder reliability across codes was 0.92 for pre-drawings and 0.88 for post-drawings. We used Fleiss's Kappa for intercoder reliability, as this statistic is appropriate for three or more coders (Hallgren, 2012). All individual codes reached a minimum of Fleiss's Kappa score of 0.8, and a minimum percent agreement of 90%. Codes and coding results are presented in tables 4 and 5. We grouped the new codes derived from this process into overarching categories (Table 5).

## Results

### *Students drew fewer stereotypic images after the intervention*

The student drawings and corresponding follow-up questions (Table 2) were used to identify student conceptions of scientists before a classroom intervention that highlighted diverse women in STEM and environmental conservation topics. Each student provided a description of the scientists' actions, and provided information about their drawings (example post-drawing in Figure 2). We first used a checklist to code for stereotypical scientist attributes in both pre-intervention and post-intervention drawings (Table 4). Within each category, the presence of at least one component counted as a score of 1, and additional components did not add to the score. For example, if one student drew a scientist in a lab coat, they received a "1" for the category "protective gear", and a student who drew a scientist in both a lab coat and goggles would also receive a "1." The largest change was in traditional scientific equipment, with 66% of students drawing microscopes or beakers with chemicals and liquids before the intervention compared to 36% of students after.



**Caption:** What is this scientist saying to you about the work you are watching the scientist do?

Type here  
 The scientist is talking to me about all the cool sea life she gets to see at work.

### Follow-Up Questions

**Instructions:** Answer the questions about your drawing. Make sure your answers are written in full sentences and answered completely.

1. What is the gender of the scientist you drew?

The gender is female.

2. Was the scientist you drew working outdoors or indoors?

indoors.

3. Was the scientist you drew old or young?

old.

4. What was the scientist doing in your picture?

she was showing me pictures of all the animals/species she gets

5. Why did you select this scientist to draw?

I tried to draw the scientist from my breakout room at exhibition. <sup>to work with.</sup>

6. Is there anything else you'd like to share about your scientist drawing?

Nothing else.

Figure 2. Example student drawing and responses to questions. This drawing was completed after the intervention activity.

Table 4.  
*Stereotypical scientist attributes.*

Category	Coding	Pre		Post	
		N	%	N	%
Gender	If Male	15	45.5	10	30
Age*	If old	9	27	8	24
Location*	If indoors	27	81	24	73
Protective gear	If wearing lab coats, safety goggles, or other protective gear	14	42	6	18
Traditional scientific equipment	If there are microscopes or glassware with liquids	22	66	12	36
Scientific knowledge equipment	If there were computers, clipboards, or other knowledge equipment	13	39	14	42

Note: N = 33 students.

\*coded from student descriptors instead of student drawings

We used a Sankey diagram to visualize potential shifts in the gender of scientists drawn (Figure 3). In this diagram, the size of each flow is proportional to the percent of students who drew scientists of different gender backgrounds before and after the intervention. Initially, equal percentages (45.5%) of students drew women and men as scientists. Overall, 22 students (66.67%) did not shift in the genders of scientists drawn. However, after the intervention, a smaller percentage (30%) of students drew men while a larger percentage (58%) drew women as scientists. Five students who initially drew men as scientists drew women after the intervention. Additionally, the percentage of non-binary scientists increased from 3% to 9%. A small subset of drawings could not be classified as one gender (6% before the intervention, 3% after). We grouped these drawings into a group “Other” which included students who indicated all genders, drew multiple scientists representing multiple genders, or stated that they did not know. While we identified a shift away from male drawings, this trend was not significant using Fisher’s exact test for significance.

For each student, we generated a summary score based on the number of types of stereotypical scientist attributes found in their drawings, with each item from Table 4 representing a score of 1. With six checklist items, students had a potential maximum of 6 stereotypic components in their drawings. Student scores decreased between the pre-drawings ( $\bar{x} = 3.03 \pm 1.26$ ) and post-drawings ( $\bar{x} = 2.24 \pm 1.37$ ),  $t(32) = 2.8$ ,  $p = 0.008$  (Figure 4). Overall, this represented a moderate effect size (Cohen’s  $d = 0.62$ ) (Cohen, 1988). Additionally, for each student we calculated the change in their score by subtracting their pre-score from their post-score. The average student drew one fewer stereotypical attribute after the intervention ( $\bar{x} = -0.79 \pm 1.5$ ).

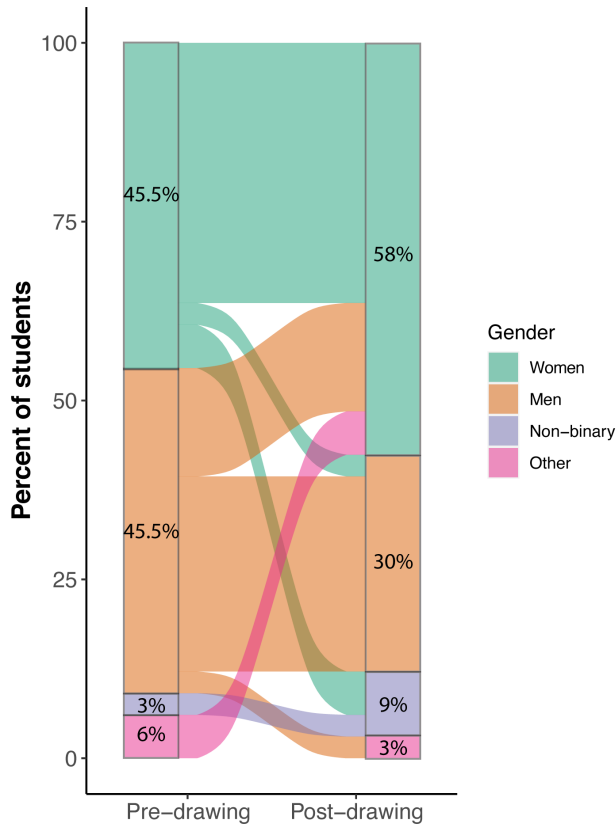


Figure 3. Sankey diagram displaying individual (N = 33) student shifts in the scientists' gender of their drawings.

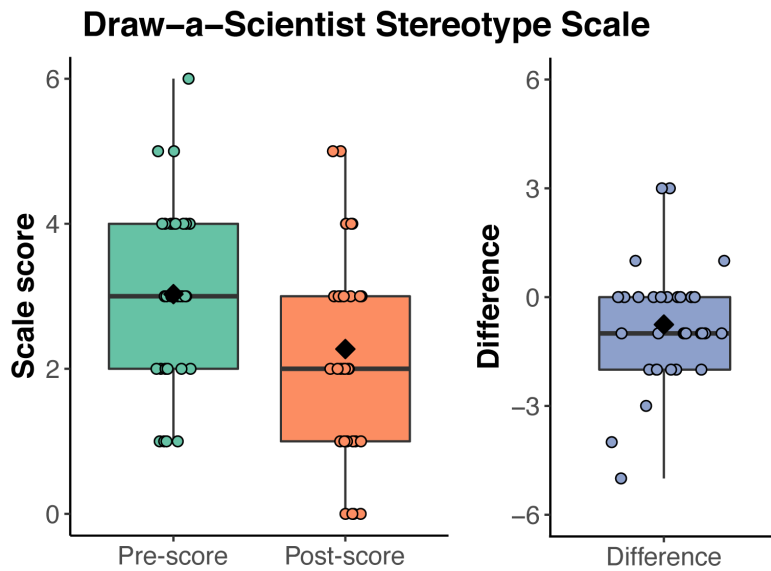


Figure 4. Boxplot of students' scale scores before and after participation in the module. Black line = median; diamond = mean; each circle = score for one student.

*Students shifted in some conceptions of science*

In addition to coding for stereotypic images, we coded drawings for discipline, and coded open-response questions asking what the scientists were doing in the students' drawings as well as what inspired their drawings. We coded field and field equipment for the presence/absence of a discipline or field equipment. For open-response questions, we used inductive coding and found that students' responses regarding the scientists' actions fell into three main categories: two actions, communicating science and conducting science, and a motivational category consisting of helping (Table 5). We coded for the presence of each code, and most responses included a single code. However, there were responses that included multiple codes, such as one from a student who *"recently saw a video by Veritasium on youtube explaining [Schrodinger's cat], and I realized that I was very interested in physics, specifically quantum mechanics."* This response was categorized as being inspired by both media and student interest. Students' inspirations for their drawings revealed that their conceptions of scientists came from personal preferences, outside influences, or came from other factors including the first thing that came to mind.

After the intervention, which highlighted multiple women in STEM but primarily focused on conservation biology, 28% more students drew biologists (Table 5). Students' captions and descriptions of their drawings revealed that their scientists' areas of research ranged from animals and plants to fungi or molecular biology, indicating the breadth of interests within biology across the student population. Additionally, student drawings became more specific. Initially, 39% of students drew scientists teaching about general scientific concepts. After the intervention, this decreased to 14% of scientists teaching, while the number of scientists conducting research slightly increased.

Students cited a variety of inspirations for their drawings (Table 5). The percentage of students citing media (e.g. TV) or family members did not change after the intervention, which is to be expected as the intervention was not rooted in these sources. Notably, six students (17%) drew scientists they were introduced to from the module in their post-drawings, with four of these students explicitly citing they had learned new information. For example, one student wrote that *"I tried to draw the scientist from my breakout room at exhibition"*, and another student wrote *"I chose this scientist because I think that Herpetology is really fascinating and I really like reptiles and amphibians are cool and amazing creatures/animals"*, indicating that the intervention impacted their conceptions of scientists and their interests in various fields. Student responses to open-ended questions about their scientists' motivation also suggest influence from the modules, with one student sharing that their scientist was *"asking the lizard if she can help the lizard."* One of the two scientists highlighted in the lesson plan comic books was a herpetologist studying Belding's Orange-throated Whiptail lizards.

A few students (one in the pre-drawings, three in the post-drawings) expressed motivation to convey personal beliefs through their drawings. Interestingly, the one student who expressed a belief in the pre-drawings noted that they drew their scientist studying vaccines because "...I didn't know what else to do but I drew a woman because I think when little kids think of scientists they just think of men and males but i wanted for people to know that women can do whatever boys can do too." This student had already considered gender stereotypes prior to exposure to the lesson.

Table 5.  
Other codes

Category	Sub-category	Code and Definition, with example student quotations	Examples:	Pre		Post	
				N	%	N	%
<b>Field</b>		If Biology		16	48	25	76
		If there was field equipment		2	6	3	8
<b>Action done by the scientist</b>	Verbal	Teaching and/or demonstrating about scientific concepts (when it's unclear it is data that the scientist has generated). Includes general advice	<i>Example figure caption: "The scientist is cracking open a geode and telling me about the different rocks that make up a geode"</i>	14	39	5	14
		Communicating their own research (for example showcasing their study organism)	<i>Example figure caption: "He is telling me that he is studying a bioluminescent fungus and you can see the fungus on one of his tables in my drawing."</i>	5	14	3	8
	Experimental	Observation research (there's no "experiment", the scientist is just collecting observation data with the goal of increasing knowledge)	<b>Example response to "what was the scientist doing in your picture?"</b> <i>"The scientist was looking at native plants."</i>	7	19	14	39
		Basic research - there is an experiment/independent variable (e.g. mixing chemicals; testing) with the goal of increasing knowledge. This includes testing to find cures	<b>Example response to "what was the scientist doing in your picture?"</b> <i>"Testing the pinch force of a new species of fish"</i>	15	42	10	28

		Planning - experimental design	<b>Example response to “what was the scientist doing in your picture?”</b> <i>“Calculations to see how he can improve the covid vaccine”</i>	1	3	2	6
		Learning about other research that's been done before	<b>Example figure caption:</b> <i>“The Scientist is showing me how to find accurate information on a species.”</i>	1	3	2	6
<b>Scientists’ motivation</b>	Helping	Helping animals	<b>Example figure caption:</b> <i>“She is asking the lizard if she can help the lizard.”</i>	0	0	3	8
		Improving lives (e.g. curing diseases)	<b>Example response to “what was the scientist doing in your picture?”</b> <i>“Discovering cures or something”</i>	7	19	4	11
		Improving the environment	<b>Example response to “what was the scientist doing in your picture?”</b> <i>“She was trying to make big mushrooms that cure air pollution”</i>	1	3	4	11
<b>Inspiration for drawing: student responses to “why did you select this scientist to draw”</b>	Preferences	Future goals/job that they want	<b>Example response:</b> <i>“Because i want to do some thing just like that when i grow up”</i>	5	14	1	3
		Student expresses preference (liking) a field or scientist (this can include thinking something is cool)	<b>Example response:</b> <i>“I chose this scientist because I think that Herpetology is really fascinating and I really like reptiles and amphibians are cool and amazing creatures/animals.”</i>	11	31	10	28
	Based on Outside Influences: includes the student being inspired to draw their	TV/movies/videos	<b>Example response:</b> <i>“I see a lot of movies and when I see scientists in them I see them wearing a gas free suit”</i>	2	6	2	6
		Famous scientists	<b>Example response:</b> <i>“Because he reminds me of my old school and also we</i>	2	6	1	3

	<i>scientist by someone/ something</i>	<i>talk a lot about him and he is really famous. My scientist is Albert Einstein"</i>				
	Family members	<b>Example response:</b> "He is a chemist like my dad"	1	3	1	3
	Scientists from the module	<b>Example response:</b> "I tried to draw the scientist from my breakout room at exhibition"	0	0	6	17
	Students wanting to convey a message or their personal beliefs through their drawings	<b>Example response:</b> "Well I chose to draw her finding a cure for a bug cause I didn't know what else to do but I drew a woman because I think when little kids think of scientists they just think of men and males but i wanted for people to know that women can do whatever boys can do too."	1	3	3	8
Other	Not knowing what scientists do	<b>Example response:</b> "Because I don't really know what other scientists do."	1	3	1	3
	First thoughts that came to mind or what students think of when they think of scientists	<b>Example response:</b> "I selected her because it was the first image that came to my head."	15	42	11	31
	Recently learned information	<b>Example response:</b> "I was thinking about the scientist at our math and science exhibition."	0	0	6	17
	Other	<b>Example response:</b> "The scientist is generic without much detail so there was no real defining traits"	0	0	3	8

**Note: N = 33 students**

## Discussion

We implemented the *In Their Eyes* conservation and comics module and characterized students' drawings of scientists. We found that student conceptions of scientists shifted (Table 4). Overall, students drew fewer stereotypical attributes after exposure to real-world scientist role models through trading cards, comic books and guest scientists (Figure 4).

### *Shifts away from traditional conceptions of scientists*

In our study, student drawings both before and after the intervention included fewer stereotypical scientist attributes than previous DAST studies. In particular, before implementation of the program only 45.5% of students drew male scientists, and less than a third drew middle aged or older scientists (Table 4). Previous meta-analyses have found that studies consistently find that the majority of students draw male scientists (Ferguson & Lezotte, 2020), although this has been decreasing in recent years (Miller et al., 2018). Of note, the students participating in the module were enrolled in four classes with two women teachers, all from one highly diverse Title I school. Previous studies have shown that teacher gender can mediate girls' concerns about being negatively stereotyped in the classroom (Master et al., 2014). The students' science classroom environment may have impacted their pre-existing perceptions of scientists. However, our findings are consistent with a recent finding that fewer students are including gender as a defining feature of scientists when they draw scientists (Gormally & Inghram, 2021). Collectively, our study adds to the growing body of literature supporting a general shift away from traditional conceptions of scientists.

Our coding revealed additional trends in students' drawings (Table 5). The percentage of biologists included in students' drawings increased from 16 (48%) to 25 (76%). This shift supports the influence of the module, as all of the scientists featured in this study were in the biological or climate sciences. Additionally, six students drew scientists from the module. Collectively, this indicates to us that exposure to real life scientists influenced students' perceptions of scientists. Interestingly, the number of students who described the scientists drawn as conducting observational research doubled, from 7 (19%) to 14 (39%). This corresponded with a decrease in traditional scientific equipment (Table 4), indicating that students' perceptions of what constitutes scientific research had been broadened. These codes were based off of student captions and responses to questions asking them to describe what the scientists were doing. Other recent studies have shown shifts away from traditional perceptions of science, and have found that in light of the ongoing COVID-19 pandemic a sizable percentage (28%) of elementary school aged children are representing scientists as medical researchers (Quílez-Cervero et al., 2021).

Role model interventions are wide-spread, with goals of increasing the representation of women in STEM (Casad et al., 2018). Exposure to female scientists through career talks in schools

increases girls' preferences for STEM (González-Pérez et al., 2020). Science outreach often uses in-school visits (e.g. a scientist-in-the-classroom model) for exposure to scientists (Laursen et al., 2007). This type of outreach significantly positively influences student attitudes towards science, in particular for underrepresented students (Gall et al., 2020). However, barriers such as access to guest scientists can prevent their use in the classroom. Our findings support the efficacy of online guest scientists and trading cards and comics as effective low-cost tools that can influence student conceptions of scientists.

#### *Limitations and recommendations for future studies*

There are certain limitations to consider when interpreting the results from this study and that should be considered in future work. First, the module was implemented during the COVID-19 pandemic, and consequently took place remotely. The pandemic resulted in documented negative impacts for student engagement and learning (Darling-Aduana et al., 2022). We did not collect data about student engagement online, for example if students used the comic books and trading cards beyond their remote synchronous class periods. Future implementations of this program should include focus group interviews with students to identify student perspectives about each aspect of the program, in particular the influence of the trading cards, comic books, and interactions with scientists.

Due to a variety of factors, including consistency of lesson plans for teachers during hybrid instruction, this study design consisted of pre-post measuring changes in conceptions for students after exposure to women role-models in STEM. A significant limitation of this work is that with a one-group pretest-posttest study design we were unable to include a control group. While it is promising that the percentage of women scientists in drawings increased after the intervention, this trend should be compared to drawings when students receive curricula with both men and women. Future iterations with a larger sample size should use a randomized control design in order to measure the effects of the intervention compared to exposure to a control (Dimitrov & Rumrill, 2003). For example, the curriculum could be implemented with randomly assigned classrooms receiving all-male representation of scientists throughout the comics, trading cards and educational aspects, other classrooms receiving all-female representation, and still other classroom receiving a mixture of scientists in the materials.

Relatedly, as the intervention involved multiple aspects that included a focus on women in STEM (including women being featured in comic books, trading cards, and a virtual poster session with guest scientist moderators), it is unclear which aspect of the module contributed most to the changes in student conceptions of scientists. Meeting role models and having live interactions may have differential impacts than reading about role models (Kearney & Levine, 2020). Additionally, due to the limitations of virtual poster sessions the students were all introduced to the guest scientists during a whole-class discussion but spent the majority of the

poster session in a breakout room with one scientist moderating their presentations. In-person instruction would allow for students to potentially have more meaningful interactions with other scientists. It will be important for future work to explore if the program holds similar impacts when implemented through in-person instruction, and to explore each aspect of the module individually to assess impacts of individual components, in particular for educators who may prefer to implement fewer aspects of the module.

An additional limitation of this case study is the small sample size. Although there were 112 students enrolled in the participating classrooms, we were only able to collect and analyze 33 of these students' drawings and responses, for a participation rate of ~30%. We compared self-reported student demographics (Table 3) to publicly available school demographics, which suggested that our sample may be representative of the classroom. However, with these low participation numbers we encourage caution when generalizing our findings beyond the included sample of students.

Finally, the DAST itself and questionnaire provide limitations to the information we can gather from student drawings. The questions we posed asked students to identify their scientists' gender, location of work, and provide descriptions of what they were doing, but we did not ask about other demographic variables such as scientists' race and ethnicities. Moreover, we did not ask students to draw non-scientists, and so we cannot explore from this dataset alone if students perceived scientist genders differently from other professions. Future iterations of this program should include interviews with students to explore these ideas in more depth. Interviews could explore nuances in the types of actions being done by scientists, and should include targeted questions about students' motivations and influences for their drawings.

#### *Recommendations for educators*

As part of our module development, we created a free resource guide ("Teacher Packet") and provided materials at <https://www.nps.gov/cabr/learn/kidsyouth/ite.htm>. We encourage educators to view the Teacher Packet, which includes options for virtual and in-person instruction.

These materials were designed for place-based education with schools in San Diego, but could be adapted for other environments, ecosystems, and contexts. For example, educators could have students design their own trading cards based on local scientists, or their own comic books based on local organisms and parks.

In the design of our program, we reviewed the DAST literature and found that past literature had used checklists that were limited in scope and potentially out-of-date (Ferguson & Lezotte, 2020). We modified questions used in previous studies (Farland-Smith, 2012) and used inductive coding in order to identify additional codes that more holistically captured students' inspirations for their drawings and descriptions of scientists' actions (Table 5). These codes

should be tested in additional contexts, but could be used by other educators as a way to categorize student drawings.

With the ongoing COVID-19 pandemic, this module was adapted for hybrid instruction which introduced challenges for assessing student engagement. Additionally, with our small sample size we are cautious to make generalizable statements about our findings, but we encourage educators to implement aspects of the module and use our codebook (Table 5) to identify changes in student conceptions of scientists.

## Conclusion

This study provides support that comics are an effective teaching tool in the classroom, and that exposure to real world role models through trading cards and virtual classroom visits impacts students' conceptions of scientists. Educators can use the -module in their classrooms. As we scale the program, we intend to develop lesson plans for multiple age ranges that are aligned with NGSS, and a larger set of trading cards to increase the diverse pool of representative scientists.

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