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Perceptions of scientists held by US students can be broadened through inclusive classroom interventions

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More diverse representation in undergraduate classrooms may be an important step towards turning science, technology, engineering, and mathematics (STEM) disciplines into more inclusive communities. In the United States of America, the individuals whose work is discussed in typical introductory science courses collectively do not represent the diversity of students' identities in the classroom and further reinforce existing stereotypes of scientists as male, white, and aged. Here we report on the implementation of a semester-long intervention in an introductory-level geoscience course at the University of South Florida, USA. We introduced students to individuals with marginalized identities who are either scientists or have had a major influence on science and conducted semi-structured interviews with students from the course's previous semesters. Analyses of these interviews indicate that participants with marginalized and non-marginalized identities broadened their preconceptions of who belongs in science and the range of identities among scientists. We suggest that interventions like these could foster feelings of belonging in the STEM community and, with repeated efforts, reduce harmful stereotyping and microaggressions against under-represented scientists.

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In introductory science courses, instructors and textbooks often present students to the "greats"—the scientists who developed the unifying theories and concepts for that particular subject[1,2]. There is an easily identifiable common thread that links most of these "greats" (e.g., Charles Darwin, Alfred Russel Wallace, Nicholas Steno, and Alfred Wegener) together: they are white American and European men, generally depicted late in their career. By including only aged, white men in our textbooks and lectures, we continue to reinforce the dominant, but incorrect, narrative that has existed for centuries—that white men have been the predominant contributors to new scientific knowledge. Throughout history, this select group of scientists has dictated who has been able to serve in scientific leadership capacities (e.g., the exclusion of women from scientific academies[3]), and has decided whose contributions are considered significant (e.g., the historical exclusion of Indigenous researchers from authorship in scientific articles[4])[5]. In not questioning this narrative, we contribute to the history that has actively ignored or prevented the advances of scientists with marginalized identities (e.g., Black, Indigenous, and People of Color (BIPOC), people with disabilities, lesbian, gay, bisexual, transgender, queer, and genderqueer (LGBTQ+) people, women, people with multiple marginalized identities). Our acquiescence perpetuates a specific history that treats scientists with marginalized identities' contributions to scientific ideas and developments as unusual or uncommon, which is not the case[2,5,6].

Furthermore, the lack of representation significantly impacts the students we are teaching. Introductory science courses in higher education are where students begin to imagine themselves in a scientific career. Multiple studies[7–9] have reported white, older males as the dominant stereotype found in students' perceptions of a "scientist." This viewpoint can contribute to students with marginalized identities' lack of interest in pursuing a career in science, as they do not "see" themselves as a scientist or feel welcome in science[2]. If the scientists we introduce do not represent our students, and we do not acknowledge the diversity within our student bodies and within the scientific community, students will not feel a sense of belonging[10]. Lee[5] notes, too, that unless BIPOC students attended minority-serving institutions, these students are unlikely to have had science faculty who share their backgrounds. Inclusive representation can have an extremely positive effect in reducing harmful impacts/outcomes like imposter syndrome and in increasing a student's feeling of belonging[11–16].

A lack of inclusive representation throughout the formative education process skews interpretations of who belongs in science, which is reinforced throughout formal education. An example of this can be seen from studies examining what children and adults think of when they hear the word scientist—in studies that ask people to draw an image of any scientist, the broad majority draw a white man[17]. This leads to students from privileged backgrounds (e.g., white, cisgender, male, and non-disabled) committing both unwitting and witting microaggressions when they meet scientists and science students with marginalized identities[18,19]. Microaggressions, along with more directed harassment, have the ability to create extreme stress for underrepresented students, especially for those who hold multiple marginalized identities (e.g., women of color)[20–22], and can lead them to leave STEM entirely[23–27]. This means that changing stereotypes and mental images about who belongs in science is critical for building and retaining a more inclusive science community. As STEM as a whole has not made significant progress in increasing the recruitment and retention of scientists with marginalized identities[28], it is imperative that the STEM community continues to work to shift the culture to increase inclusivity.

Although some change to diversity in STEM has occurred (e.g., representation of women has increased in the geosciences; however, the majority of this increase has been limited to white, non-Hispanic women[29]), ingrained stereotypes of who belongs in STEM persist and have negative impacts for scientists with marginalized identities. For example, women are cited at a lesser rate and receive more journal rejections than men, a statistic that cannot be explained by the reputability of the science itself[30]. Black people are cited less and receive fewer grants than their white counterparts, especially when grants concern diversity and inclusion work[31]. Studies have shown that senior white men choose to place their sponsorship (i.e., leveraging their own power and influence to advance the career of others) on other white men[32]. This issue continues to compound throughout careers, as fewer article acceptances, citations, and awarded grants translate to fewer scientists with marginalized identities being hired into tenure track jobs and promoted, creating a largely homogenous scientific community. A homogenous scientific community can have critical effects on inclusion. As an example, disabled scientists are often not included when policies and procedures are being developed, leading to ableist policies that do not account for the needs of the disabled community; this occurs frequently in field-based sciences, where mandatory field courses often impede participation from students with disabilities[33]. Clearly, a lack of inclusive representation is problematic, as important decisions are made without all voices being considered.

In recent years, there has been a wealth of published material about why diversity and inclusion are critical to the furthering of science[10,29,30,34], as well as recommendations from scientists with marginalized identities for building a more inclusive science community[23,35]. Many other studies indicate the positive impact that inclusive representation has on specific groups of students, such as: women[14]; first-generation college students[11]; D/deaf or hard of hearing students[12]; and BIPOC students[15].

Purpose of study and ontology. This inquiry is informed by several bodies of literature: the nature of science (NOS), stereotypical images of scientists, and self-concept. While other ontologies could be applicable here, these three bodies of literature are the most suitable for this particular analysis. The research question is guided by these bodies of literature and helps to define the methodology of the study, as well as to interpret the results. The research question is as follows: in what ways does implementing an in-class diversity intervention impact student perceptions of science and scientists?

In this study, we assess the ways in which implementing an in-class diversity intervention ("Scientist of the Week") impacts student perceptions of science and scientists in a geoscience college class. We use semi-structured interviews and code for major themes. We find that most of the students broadened their conceptions of scientists and scientific identity as a result of this intervention.

Nature of science. Science is a human enterprise and is therefore tied to human attributes. Abstract concepts such as culture and biases shape the way science is perceived by an individual. The literature on the NOS helps to define what science "is" and how it is "done". However, there is no universally accepted definition of NOS, but rather a general body of agreed upon ideals[36]. One of the forerunning organizations of experts on the NOS, American Association for the Advancement of Science (AAAS), explains the NOS to be the processes for doing science, and science done as an enterprise[37]. Other researchers[36] summarize the NOS to explain science as a way of knowing and how scientific knowledge is developed, while others[38] break NOS into distinct categories: science as a body of knowledge, science as a way of thinking, science as a way of investigating, and science and its interaction with technology and society. Our inquiry is guided by the AAAS definition of NOS more so than the others, because of the broad "science as an enterprise" questions in the interview protocol.

Stereotypical images of scientists. Researchers have established the stereotypical image of a scientist as a mature, white male[9]. Study after study[7,39–43] continue to confirm this stereotype with little to no variation among findings. Moreover, K-12 educators themselves have been found to hold stereotypes of scientists[44,45] which has the potential to influence how they teach and who they wish to showcase as scientists in their classrooms. Inaccurate teacher perceptions of scientists were found to be created during their preservice education in science courses (i.e., teachers perpetuating the cycle of stereotypes to future teachers)[46,47].

Self-concept. Self-concept is a person's perception of themselves influenced by their environment and others involved in that environment[48]. A person interacts with their environment and responds to physical or symbolic features within that environment, and this interaction creates one's personal perception of themselves. In an academic setting, self-concept can be referred to as a person's perceptions of their abilities in a certain academic environment[48,49]. The STEM fields create a unique academic environment, allowing for academic self-concept to play a role for students who are not considered the "norm" in that environment. As an example, gender disparity is high in most STEM fields, which has the effect of decreasing women's sense of belonging and causes an increasing disinterest in pursuing STEM majors[50].

Results

Three overarching themes were identified throughout the 14 interviews. These themes are: (a) stereotypes of NOS, (b) new conceptions of NOS, and (c) science identity. Exemplary quotes from participants with pseudonyms are provided to illustrate identified themes (Table 1). From the lens of our ontologies, the theme "stereotypes of NOS" is contained under the body of literature on stereotypical images of scientists, the theme "new conceptions of NOS" is contained under the body of literature on NOS, and the theme "science identity" is contained under the body of literature on self-concept.

Stereotypes of NOS. Many of the statements coded under the theme of "stereotypes of NOS" alluded to scientists as older, white men; both Alex and Pray Tell referred to scientists typically being white men in quotes highlighted in Table 1. Furthermore, comments from participants indicate an expansion of their ideas on what scientific careers looked like and challenged stereotypical images of scientists. Participants mentioned science communicators, educators, activists, and field scientists as well. Quentin stated, "there's a misconception that scientists are like…there's like a template for scientists and like lab coats and playing with beakers and stuff like that." One specific example that appeared across multiple transcripts is participants' association of Greta Thunberg, the Swedish young adult climate activist, as a contemporary example of someone who expanded their views of science identity. For example, Josh stated "…I don't know if we talked about Greta Thunberg, but I felt like she was a good example because I love the environment and that's why…that's my major, so I wanted to make a change because I look up to her." It should be noted that Thunberg is considered to be an activist, and not a scientist; however, this is Josh's perception of her. Students such as Josh exhibited an understanding of core NOS ideas such as 'science as an enterprise' through this intervention.

New conceptions of NOS. The statements residing under the "new conceptions of NOS" theme indicate that the majority of participant perceptions of "scientists" showed change to an understanding of science as having a broad diversity of practitioners. For example, participants mentioned that they had not realized the societal barriers in place for scientists with marginalized identities (in particular, D/deaf or hard of hearing, women, and immigrant scientists were mentioned). Once barriers were recognized, new knowledge relating to the diversity in science surfaced. Participants were able to "see through" the barriers and acknowledge and celebrate the broad diversity of the scientific community. For example, Alex stated: "…there's people of different races, different backgrounds… different genders. Somebody, I believe, was either gender neutral or used they/them pronouns and that was really cool because I had also never seen that…in terms of a scientist that's well known."

Science identity. Students began to see scientists as relatable to themselves, or humanized to a degree in which they could be friends with or talk to scientists on a personal level. For example, Sophia stated: "I guess since I'm not a science major, per se, but I did feel kind of like the history coming through and I felt like more connections of what different people did instead of it just being like a fact that we know." Humanizing scientists allowed for

Table 1 Examples of statements made by participants that are representative of each theme.

Theme	Description	Examples
Science identity	How the participants view themselves personally, outside of their educational paths or career. Also, how participants viewed their careers or majors and their future work-related identity.	"… I know we talked about a queer scientist, I'm queer, so that's the connection…"—Josh "I would say it [the intervention] actually made me switch my major"—Jessica
Stereotypes of NOS	How they thought about science and scientists before this intervention and subsequent interview. Also, who or what they considered scientists to be.	"… K through 12 education, when we learn about scientists, are usually white, male, and rich, and very little do we find out about anybody outside of that bubble."—Pray Tell "…When you think of the word scientist usually you would think of a tall white man"—Alex
New conceptions of NOS	Recognitions from participants about scientists and their existence outside of their career, as well as the impacts that science can have outside the scope of traditional research. Also, recognitions from participants about new ideas they had as a result of the Scientist of the Week intervention about science/scientists.	"…Most of them seemed more like normal people than I think…none of them were scientific titans or anything like that. I think in that way I connected more"—Secretariat "…There were women who were contributing at the time but not being recognized for that work-you know, that was pretty eye-opening to me"—Laura

The pseudonyms here were chosen by the participants.

the students to see themselves as capable of becoming scientists or developing a scientific self-concept either presently or in the future. It also allowed students who had no intentions of being a scientist to better understand that scientists are not elite groups of people, but people similar to them.

Although the goal of this intervention was not to cause students to become STEM majors, one student, Jessica, did suggest they would change their major because of their changed perceptions: "…and that really influenced me and it made me kind of switch my path to becoming a scientist." Others grew an appreciation for science, and seeing people like them doing profound things inspired them. For example, Pray Tell stated, "So, seeing scientists that look like me doing things, miraculous things is very inspiring." The aforementioned statements are just a few examples of how students were able to develop and/or grow their self-concept in a STEM field via the rich representation of scientists in this intervention.

We also identified positive shifts in perceptions by participants who hold at least one non-marginalized identity (e.g., white, male, hearing, neurotypical, and cisgender) that indicate a broadened conceptualization of the scientific community. For these quotes, the reader can assume that the participants have identified themselves as not belonging to the marginalized groups they mention. Alex stated "…I remember one of the scientists had autism, and I thought that was cool because I had never heard of that before," indicating a broadened perception of the diversity of the scientific community. Pyrite shows an expanded idea of societal barriers in place that prevent full access to D/deaf and hard of hearing scientists: "It's not that I didn't think that Deaf people couldn't be scientists. I'd just never realized how, how much it affects them differently." Sam Porter states: "Basically, with the scientific work of like Mary Anning…it really helped not only paleontology as a field, but it also helped women get a foot hold in the scientific world," indicating a broader understanding of the historical advances of women in science (note: Mary Anning was not used as a scientist of the week, but she was discussed during lecture).

Discussion

This intervention brought forth an awareness of scientific stereotypes and influenced perceptions of the NOS. Participants identified their held stereotypes, reflected on them, and began to change their ideas of what a scientist "looks" like. Participant Pray Tell stated, "…scientists don't always look like you think they look like. They're not always, you know, lab coats, with a beaker kind of scientists. There's scientists of all different hues and shapes and varieties." This quote indicates this participant's emergent understanding of a more inclusive and diverse scientific community, adding to growing efforts to increase inclusive representation in STEM. The breakdown of scientific stereotypes in students' minds has large implications for culture shifts in STEM.

Not only is the recognition of an incorrect perception of the NOS necessary, but after reflection, a shift in perception leads to a deeper understanding of the NOS. The shift in perceptions of the NOS in the participants is shown in this quote, also presented in the results, by Alex: "…I remember one of the scientists had autism, and I thought that was cool because I had never heard of that before." This reveals not only an awareness of NOS stereotypes, but that after reflection, this participant now understands that neurodiverse scientists exist. This shift in perception of the NOS is a critical step towards challenging the white, male-dominated stereotype that has often been illustrated by students (e.g., in Draw a Scientist[9]). In this study, students were able to identify with scientists or see themselves as able to become a scientist, therefore seeing themselves as being able to join the scientific community. For example, Jessica states: "I could truly begin to see myself in their shoes…which I guess I kind of already am a scientist." Sam Porter also states, "Some of them I remember being, you know, people of color and sometimes people that weren't from this country coming to work in this country, which I can relate to myself and that really motivated me to strive for bigger things."

Not only is it important for students with marginalized identities to see themselves represented in STEM, but it is also critical for students with privileged identities to see scientists with marginalized identities. These students with privileged identities are a large part of the solution in making cultural changes in STEM. As microaggressions are often cited as a reason for people with marginalized identities feeling unwelcome in the STEM community[20–22], reducing stereotypes and broadening perceptions of who scientists are is a critical action towards creating a more inclusive STEM community. In this study, comments by participants such as Pyrite, Alex, and Sam Porter about autistic, D/deaf, and women scientists indicate that this intervention caused them to think more broadly about the diversity of the scientific community and about how systemic barriers have prevented the full participation of scientists with marginalized identities. Other similar studies have suggested that with proper intervention, students can change their stereotyped images of scientists to include a more diverse community[51].

Although this intervention was successful in expanding "new conceptions of NOS," one participant's statement stood out in particular as interesting, as it brought up a persisting gender-biased stereotype. Jessica stated: "…and how cool that was [science communication initiatives (e.g., Skype a Scientist)]…for all those little boys who love dinosaurs to talk to a real paleontologist and think, wow, I could be a paleontologist." Students who have had their conceptions of scientists expanded still associate concepts like "dinosaurs," and by extension paleontology, with being male, indicating that changing stereotypes will take repeated efforts.

Future work. To assess the full impacts of interventions such as this, interventions should be replicated at a range of institutions, including primarily white institutions (PWIs), historically Black colleges and universities and tribal colleges and universities. For example, it is possible that we might see larger gains in BIPOC students' sense of belonging in STEM if this intervention is carried out at a PWI, where BIPOC students may be less likely to meet BIPOC science faculty[5]. We may also see larger gains in broadening the perceptions of students with privileged identities at PWIs for the same reason. Future work could also assess how this intervention may change the perceptions of the educators themselves by making them more aware of who is being represented in their course material. This could be impactful especially considering that educators' perceptions of scientists can be formed during their own preservice education, causing a continuation of these stereotypes being passed on to their students[46,47].

Future work should also analyze specific gains in broadening perceptions and feelings of belonging in the scientific community for individuals with specific marginalized identities, following established targeted strategies for increasing retention (e.g., policy changes concerning sexual harassment to increase retention of women in science[23]; specific mentoring programs for women[52] and students of color[53,54]; intersectional programs for students with multiple underrepresented identities, such as women of color[22]; and safer campus climates for LGBTQ+ faculty[55]). Future studies using this intervention should explore how individuals within specific marginalized groups are affected by interventions such as these to illuminate possible areas of improvement for the intervention.

Conclusion

Inclusive representation is a critical first step in ensuring that students can see themselves belonging to a community and in reducing harmful stereotypes that can push underrepresented students out of STEM degrees and careers. Without inclusive representation, we risk teaching a narrow and inaccurate history of science that excludes the work of scientists with marginalized identities. All science educators need to be mindful of who they are introducing in their classrooms and how[56,57]. This study indicates that simple acts, such as introducing an inclusive representation of scientists in an introductory course, can begin to change stereotypes of scientists. However, inclusive representation cannot be the only step that is taken if we expect to effect change. In order to more effectively increase the retention of scientists with marginalized identities and build a more inclusive community, we must listen and learn from these students, faculty, and staff who hold these identities.

Methodology

In this study, we assessed the impacts that diverse representation had on introductory science students through a semester-long classroom intervention. A step-by-step recommendation for implementing interventions like this in classrooms, with examples of discussion points and biographies of the scientists of the week, is provided in Supplementary Note 1. Our overarching goal was to determine the extent to which interaction with and exposure to the work of scientists and individuals with marginalized identities who have made great contributions to science broadened students' conception of science and scientists within STEM fields. While the majority of the people highlighted in this intervention were scientists, people who are science activists or people who had a major influence om science were also highlighted and their roles in the science community were explained to students. This was done for the purpose of reducing stereotypes of who belongs in science and increasing the sense of belonging for students who hold marginalized identities.

Methods and study population selection. We sought to determine in what ways students' perceptions were changed toward science and scientists because of the Scientist of the Week intervention. We used semi-structured interviews with open-ended questions. We used this qualitative research strategy to capture more detailed information (e.g., feelings and attitudes) from individuals about how and why they were impacted by the intervention. Interviews were more appropriate for an explanatory case study[34] such as this, because while quantitative research methods like surveys can tell us how frequently something occurs, qualitative methods like interviews can help tell us why[58,59].

Study population. Only students enrolled in S. Sheffield's introductory geology courses during 2018 were considered for participation in this study. Students who were enrolled in S. Sheffield's courses during the time of the data collection for this study (Fall 2019) were excluded to prevent students from feeling that they were required to participate. A list of eligible students was created by S. Sheffield; eligible students were those who had an above-average attendance record or had a record of engaging in the course material (e.g., actively participating in lectures), because these students had the potential to give the richest data possible (i.e., purposive sampling[60]). As high interactions with the course are not synonymous with high grades, grades were not considered in student selection. We contacted 30 students, which represented ~20% of the students in the Spring 2018 courses. Of those 30, 14 agreed to take part in the study. The 30 students contacted and the 14 who responded closely represent the racial, ethnic, and gender diversity of the study institution (Table 2). In the interest of participant privacy, no demographic information is associated with the participants, unless specifically given by the interviewee during the interview.

Table 2 Undergraduate enrollment by gender, race, and ethnicity for 2018–2019 at The University of South Florida[64].

		Percentage of undergraduate student body
Gender	Men	45.4%
	Women	54.6%
Race/Ethnicity	Hispanic/Latinx	21.2%
	Black/African American	10.0%
	White	46.8%
	Asian	7.0%
	Native American	0.2%
	Native Hawaiian/Pacific Islander	0.1%
	Two or more races	3.9%
	Nonresident	7.2%
	Unknown	3.4%

Total number of undergraduate students enrolled was 32,238. Nonresidents are international students. All race/ethnicity categories except Hispanic/Latinx specifically exclude Hispanic/Latinx (originally listed as Latino[64]).

Although the sample size could be considered small relative to the students who have taken this course, we feel confident that the interpretations of the data highlight important themes. In line with published qualitative research[61], we were more interested in understanding the essence of the intervention instead of how many participants were interviewed.

Interview methods. The interview protocol followed a semi-structured format, meaning the research personnel gave a general structure to the interview but allowed the interviewee freedom to discuss the topics as they saw fit[62]. Semi-structured interviews are best suited for case studies involving a limited population, such as this study. Four predetermined questions were written before the interviews took place; these questions were designed to be open-ended to allow the participants to answer freely. The questions are as follows: (1) what do you remember about the Scientist of the Week program?, (2) did your ideas or feelings about what science or scientists are change after the Scientist of the Week program?, (3) did you feel any personal connections to any of the scientists in the Scientist of the Week program?, and (4) do you have any suggestions for how the Scientist of the Week program could be improved in the future? Follow-up questions for clarification on student responses were asked on a case-by-case basis.

Participants chose a pseudonym before the start of the interview and were referred to as such throughout the interview. The interviews were audio recorded to ensure transcript accuracy. The audio recording of the student was transcribed into a text file. Once the student reviewed the written transcription of the interview and approved it, the audio file was deleted to ensure anonymity. Seven of the 14 interviews were conducted by V. Ricchezza (with S. Sheffield present as an observer for the comfort of the participant); the other seven interviews were conducted by S. Sheffield. Each interviewee was given the option to have S. Sheffield leave the room for the interview, though none chose this option. Each interviewing author transcribed their own interviews.

Reliability and trustworthiness. Interviews were coded to identify themes in the transcripts via constant comparative analysis techniques[63]. S. Sheffield, M. Cook, and V. Ricchezza coded the data from the transcriptions synchronously in order to establish investigator triangulation, until saturation was reached or no new themes were identified. G. Rocabado provided independent inter-rater reliability of the codes with ~88% agreeance (46/52 codes).

Limitations. The first author of this paper, who developed the course intervention, is a white, non-Hispanic, cisgender woman; it is possible that if this intervention had been conducted by someone of a different racial, ethnic, and gender background, results may have differed. The second author of this paper—who assisted with coding, developing the ontologies, and with general writing—is a white, non-Hispanic, cisgender woman as well. The third author of the paper, who helped develop the interview protocol, conducted half of the interviews, and assisted in coding, is a white, non-Hispanic, cisgender man. The fourth author, who contributed with inter-rater coding of the data, is a Hispanic cisgender woman. It is possible that certain inherited biases of the authors could have impacted interpretations of the data. The fifth author did not code the data.

This study selected students who were most likely to provide rich information (i.e., students who actively participated in the course), so results may not be generalizable to other students who may not have engaged with the course material to the same degree.

Reporting summary. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

The codebook generated from transcripts that supports the findings of this study are available in Supplementary Data 1. Full transcriptions from interviewees are available on request from the corresponding author [S.L.S.]. The transcription data are not publicly available as they contain information that could compromise research participants' privacy and consent.

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