

Student-Authored Scientist Spotlights: Investigating the Impacts of Engaging Undergraduates as Developers of Inclusive Curriculum through a Service-Learning Course

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ABSTRACT

Scientist Spotlights—curricular materials that employ the personal and professional stories of scientists from diverse backgrounds—have previously been shown to positively influence undergraduate students' relatability to and perceptions of scientists. We hypothesized that engaging students in authoring Scientist Spotlights might produce curricular materials of similar impact, as well as provide a mechanism for student involvement as partners in science education reform. To test this idea and investigate the impact of student-authored Scientist Spotlights, we developed a service-learning course in which teams of biology students partnered with an instructor to develop and implement Scientist Spotlights in a biology course. Results revealed that exposure to three or four student-authored Scientist Spotlights significantly shifted peers' perceptions of scientists in all partner courses. Interestingly, student-authored Scientist Spotlights shifted peers' relatability to scientists similarly among both white students and students of color. Further, student authors themselves showed increases in their relatability to scientists. Finally, a department-wide survey demonstrated significant differences in students' perceptions of scientist representation between courses with and without student-authored Spotlights. Results suggest that engaging students as authors of inclusive curricular materials and partners in reform is a promising approach to promoting inclusion and addressing representation in science.

INTRODUCTION

Science, technology, engineering, and mathematics (STEM) disciplines continue to struggle to engage, effectively teach, and retain postsecondary students, both generally and particularly among women and students of color (Seymour and Hunter, 2019). Concern about these issues has spurred national reports and earnest efforts, yet widespread reform and increases in students' sense of belonging in science continues to be elusive (National Research Council, 2003; President's Council of Advisors

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on Science and Technology, 2012; Singer *et al.*, 2012). One approach to promoting inclusion in undergraduate science courses has been to address the representation of scientists in undergraduate STEM curricula, which may often present exclusionary views of who can do science and the characteristics of scientists, limiting the extent to which students may see their possible selves in these disciplines (Carlone and Johnson, 2007; Thoman *et al.*, 2015; Schinske *et al.*, 2016; Wood *et al.*, 2020; Yonas *et al.*, 2020). In particular, Scientist Spotlights—curricular materials that employ the personal and professional stories of scientists from diverse backgrounds to address course content—have previously been shown in multiple contexts to increase undergraduate students' relatability to scientists and science identity, as well as decrease stereotypes about scientists (Schinske *et al.*, 2016; Yonas *et al.*, 2020). However, college and university instructors have primarily authored these curricular materials. Additionally, undergraduate students are increasingly acknowledged as underappreciated and underutilized partners in science education reform efforts who bring cultural assets and near-peer perspectives that may be particularly relevant to promoting inclusion. Yet there are few examples of undergraduate student-instructor partnerships to promote inclusion in science teaching and a gap in the biology education literature on how students might participate as active partners in reform efforts. We revisit the influence of Scientist Spotlights on students' perceptions of scientists, acknowledge the many sociocultural assets that undergraduate students themselves could bring to science education change efforts, and explore service-learning courses as a potential mechanism for institutionalizing student-instructor partnerships to support iterative science education reform. Each of these arenas of scholarly work suggests a need for more research on how to center students as active participants and partners in reforming undergraduate STEM curricula.

Scientist Spotlights as Curricular Interventions to Counter Stereotypes, Promote Students' Science Identity, and Change Scientist Representation

Societal images of scientists surround students in their everyday lives and in science classrooms, often sending singular and exclusionary messages about who belongs in science that are in fact inaccurate. These images often portray stereotypical images of a scientist, such as a person who is white, male, possibly socially awkward, or perhaps from an affluent background with parents who were college educated or of a higher socioeconomic status (Mead and Métraux, 1957; Dikmenli, 2010). These ideas are also present in students' views of scientists. For example, a previous study investigating the types of scientist stereotypes present in a community college biology course confirmed that these scientist stereotypes were expressed by students. Further, students in that study not only expressed stereotypical images of scientists, but also lacked knowledge of real-world scientists, suggesting they might not know any scientists to whom they can relate (Schinske *et al.*, 2015). If educators aspire for students from diverse backgrounds to see themselves as scientists and persist in the field, then purposeful efforts are needed in undergraduate curricula and teaching to shift students' views about the types of people who do science to include characteristics of themselves.

To address this challenge, Schinske and colleagues (2016) developed Scientist Spotlights—brief curricular assignments implemented as either homework or in-class activities that highlight the personal and professional story of a counter-stereotypical scientist and that also address course content. Authored by an instructor, these assignments engage students in exploring related science content, reading about the scientist's personal background, and responding in writing to several prompts about these materials. Importantly, students are asked to metacognitively reflect on the content within these Scientist Spotlight assignments and reflect on what this information tells them about the types of people who do science. To assess the impact of Scientist Spotlights, previous studies have asked students—before and after doing Scientist Spotlights—to reflect on their ideas about: 1) their own relatability to scientists—whether students see aspects of themselves in the scientist under study; and 2) their current perceptions of scientist stereotypes—general descriptions of characteristics of people who do science. These two aspects of students' ideas about scientists were probed, as they are thought to relate to students' science identity and conceptions of possible selves—the cognitive way people refer to themselves, including their hopes, fears, and fantasies, which likely contributes to science identity (Markus and Nurius, 1986). In an initial study of Scientist Spotlights, researchers implemented 10 such homework assignments over a term and observed that students increased in their relatability to scientists, and more students agreed that they knew an important scientist to whom they could relate after the intervention. Additionally, in that initial study, students significantly shifted away from stereotypical views and toward nonstereotypical views of the types of people who do science. Interestingly, these results were also observed 6 months post-intervention, suggesting that these modest curricular interventions may lead to long-lasting shifts in students' science identities (Schinske *et al.*, 2016).

The positive impacts of instructor-authored Scientist Spotlights have also been observed when implemented in the form of a podcast, in comparison to the initial text-based approach (Yonas *et al.*, 2020). Students were asked to listen to nine podcasts that highlighted scientists from diverse backgrounds and then complete pre- and postassessments probing relatability to and stereotypes of scientists, similar to the original Scientist Spotlight study (Schinske *et al.*, 2016). Here, researchers found that students reported these podcasts to be a relatable and engaging method to learn about diverse scientists and specifically described the demographic characteristics of the featured scientists, such as a scientist's racial, gender, or sexual orientation identity, in their written reflections (Yonas *et al.*, 2020). These findings highlight the importance of the specific nonstereotypical characteristics of the scientists featured in these Scientist Spotlight assignments and the influence that these characteristics may have in shifting students' perceptions. While previous investigations of these Scientist Spotlight interventions have demonstrated positive shifts in students' relatability to and perceptions of scientists, these interventions were crafted by instructors, and the scientists featured were chosen by instructors. One wonders whether undergraduate students themselves could also serve as authors of these curricular materials, perhaps bringing near-peer perspectives to the choice of individuals and resources included in Scientist Spotlights.

Undergraduate Students as Untapped and Asset-Rich Partners in STEM Education Reform Efforts

Most undergraduate science education and curricular reform efforts are spearheaded by faculty instructors, not students, as most reform is thought to begin in the classroom through improved pedagogy and curricula (Henderson *et al.*, 2011). Unfortunately, science instructors in colleges and universities do not currently reflect the diversity of the students they serve. Additionally, the approaches to inclusion efforts of current science instructors—many of whom are primarily white, primarily men, and most often from higher socioeconomic backgrounds—are influenced by their own personal and professional experiences and may not be well aligned with the needs of their students coming from a more diverse array of backgrounds. Increasingly, scholars are attending to the many assets that diverse student populations bring with them to higher education classrooms, assets that are generally underappreciated and untapped in undergraduate STEM education reform efforts. Specifically, Yosso has conceptualized students' *community cultural wealth*, namely, skills, knowledge, and assets that students bring to higher education from their home communities and lived experiences (Yosso, 2005). These assets—sometimes referred to as cultural capital—reflect a variety of skills and knowledge that students from communities historically excluded from higher education have used to navigate systems not designed for them. Students bring to science classrooms valuable cultural capital—related to their linguistic skills, social networks, familial values, resistance to oppression, and personal and professional aspirations—that could inform and influence undergraduate science education, if only students were seen as partners in change efforts (Yosso, 2005). Shifting toward such asset-thinking about students—especially students of color, first-generation college-going students, and women in the sciences—could bring new perspectives and voices into change efforts, in particular science curricular reform efforts. However, little research has examined involving students as culturally knowledgeable partners in developing curricular interventions for undergraduate science courses.

Service-Learning Courses as a Mechanism for Engaging Students in Reform

While undergraduate students could bring key cultural perspectives and assets to undergraduate science education reform, such engagement would need to be in service of their own educational goals, integrated into their academic lives, authentically compensated and rewarded, and not exploitative. Service-learning courses are one potential mechanism for engaging students as partners in reform while also supporting their own educational progress through structured, credit-bearing experiential education connected to community needs (Bringle *et al.*, 1997). Across a variety of disciplines, service-learning courses have been linked to student success, improved disciplinary understanding, increased sense of self-efficacy, and in some cases increased retention (e.g., Dahlberg *et al.*, 2010; Payton *et al.*, 2015). However, service-learning courses have also been critiqued for traditionally engaging university students, often privileged and white, in volunteering outside higher education among less economically privileged communities, often communities of color (Mitchell *et al.*, 2012). Given the cultural assets of college and university students of color, in particular,

there are untapped opportunities to use service-learning courses to position these students as leaders in science courses, in particular. Through service-learning courses, students could apply their cultural skills and knowledge inside higher education to increase cultural accessibility of science courses, co-design more inclusive science curricula, and partner with instructors to diversify who is represented in the sciences. However, research is needed to investigate service-learning contexts as a mechanism of partnering with students and bringing their cultural assets to bear on science education reforms.

Investigating Student-Authored Scientist Spotlights as a Mechanism for Engaging Students as Partners in Curricular Reform through Service Learning

Based on the scholarly literature reviewed earlier, we hypothesized that engaging undergraduate students in authoring Scientist Spotlights themselves might produce inclusive curricular materials of similar impact, as well as benefit the students themselves and provide a mechanism for engaging students as partners in on-going science education reform efforts. To test this idea and to investigate the impact of Scientist Spotlights developed by students, not instructors, we developed a biology service-learning course entitled LEADS: Learners Engaged in Advocating for Diversity in Science. In the context of this 4-unit upper-division elective biology course, teams of biology students partnered with biology instructors for one semester to develop and implement three Scientist Spotlights in one of the instructor's biology courses. Using the framework established by Schinske and colleagues (2016), we investigated the impact of student-authored Scientist Spotlights by addressing the following research questions:

1. To what extent do student-authored Scientist Spotlights shift their peers' perceptions of scientists when implemented by partner instructors across multiple biology courses?
2. How, if at all, does the influence of student-authored Scientist Spotlights vary among students from different demographic backgrounds in these partner courses?
3. To what extent does authoring multiple Scientist Spotlights in a service-learning course affect student authors' own relatability to scientists and stereotypes about scientists?
4. To what extent does an independent, department-wide assessment reveal differences in student perceptions of scientist representation between courses with and without student-authored Scientist Spotlights?

METHODS

To address these research questions, we developed a biology service-learning course that engaged pairs of undergraduate students in developing student-authored Scientist Spotlights that were then implemented in their biology instructor partners' courses. We then assessed the impact of these efforts on three student populations: the large population of enrolled students in the partner instructors' biology courses, on the student authors in the service-learning course, and among students more broadly in the context of a department-wide student perceptions survey. We offer details about the service-learning course context; the course-based assessment tools and analysis approaches—including disaggregation of student evidence based on demographic characteristics and statistical comparisons among different

student populations; and finally department-wide assessment tools and analysis approaches. This study was approved by the local institutional review board for human subjects' research.

Service-Learning Course Context—LEADS: Learners Engaged in Advocating for Diversity in Science

In the context of a large, public, comprehensive university, we developed a service-learning course—LEADS: Learners Engaged in Advocating for Diversity in Science—which was the context for this study. This 4-unit biology course was an approved upper-division biology course elective for all biology majors at the university. The course included a 2-hour weekly class meeting to support students' professional development in inclusive and evidence-based science education, as well as a 2-hour weekly service-learning fieldwork component. In the context of the service-learning component, pairs of LEADS students partnered with a biology instructor outside class time to develop Scientist Spotlights that the instructor would then implement in a biology course that term. Below we describe the LEADS course students who authored Scientist Spotlights, the LEADS course partner instructors who implemented these newly developed inclusive curricular interventions, the modified format of the student-authored Scientist Spotlights, and the enrolled students in these instructors' partner courses who experienced student-authored Scientist Spotlights.

LEADS Student Authors and Biology Instructor Partners. In this initial offering of the LEADS service-learning course, 16 students majoring in biology—referred to as “LEADS students”—were recruited to author Scientist Spotlights that were implemented by partner instructors across eight biology courses reaching >1300 students in Fall 2018. LEADS students came to the course in a variety of ways, including nomination by faculty and by more general invitation, and all LEADS students identified as non-white students of color. Additionally, 11 partner biology instructors teaching eight biology courses—some of which were co-taught—were recruited to partner with these LEADS service-learning students to author Scientist Spotlights for implementation in one of their courses. All recruited biology instructors had previously completed pedagogical professional development in evidence-based and inclusive science teaching, were chosen based on interest in the LEADS program, and were compensated for their involvement in the effort. Pairs of LEADS students were partnered with the instructor(s) of a single biology course, usually for a course that they had previously completed, and tasked with developing four Scientist Spotlights with the support and collaboration of their partner instructor. Instructors and student partners met weekly to discuss upcoming course content as the LEADS student authors developed their Scientist Spotlights. Instructors also collaborated with students to edit these Scientist Spotlights for their courses. Further information about the LEADS course is described in Appendix A in the Supplemental Material.

Student-Authored Scientist Spotlights—Addition of an “About the Author” Section. Collectively the 16 LEADS students developed 64 Scientist Spotlights, addressing a range of biology course content and highlighting scientists from a variety of backgrounds, that were used by partner instructors in their courses (see Appendix B in the Supplemental Material for

a full list of Scientist Spotlights). These student-authored Scientist Spotlights—with the addition of an “About the Author” section—followed the same format as originally described by Schinske and colleagues in the initial description of these curricular pieces (Schinske, *et al.*, 2016; www.scientistspotlights.org). Each ~1-page assignment began with a photo of the individual being highlighted alongside a ~100-word introduction to the scientist and the course topics to which the scientist's professional work may connect. As with previous instructor-authored Scientist Spotlights, this was followed by two weblinks. The first link was to a biographical resource—usually a reading or video—that featured relatable, counter-stereotypical aspects of the individual's personal life and background, while the second link was to a content resource that introduced biology concepts related to the scientist's work, often through a popular press article, a journal article excerpt, or a video about the scientist's professional work. To honor the intellectual work of the student authors, we also decided to include the “About the Author” section at the bottom each Spotlight assignment. While brief, this section generally included three components: 1) a picture of the author, 2) a two- to three-sentence biography of the student author, and 3) a one- to two-sentence explanation of why the student author chose to spotlight the scientist (see weblinks in Appendix B in the Supplemental Material).

Enrolled Students in LEADS Partner Biology Courses. Those students who were enrolled in the biology courses taught by LEADS partner instructors—referred to as “enrolled students”—completed Scientist Spotlight assignments related to this research as part of their regular course work and were given regular course credit for completion of these. Enrolled students represented a wide range of students, as these courses included both non-majors and majors biology courses, as well as introductory and advanced biology courses. To preserve course and instructor anonymity, these courses are referred to only by a letter—B, C, D, E, F, G, I, and J—and not by course number or topic area. Enrolled students in each course completed five to six written assignments that were analyzed for this study. These included a two-question preassessment assignment about students' relatability to and perceptions of scientists, either three (courses B and J) or four (courses C, D, E, F, G, I) homework assignments to complete student-authored Scientist Spotlights during the term, and then a final postassessment assignment with the same two questions as the preassessment. All assignments were completed and submitted to the institution's online learning management system as part of regular course work.

Course-Based Assessments of Impact of Student-Authored Scientist Spotlights

To gauge whether student-authored Scientist Spotlights could have impact similar to what was previously seen with instructor-authored Scientist Spotlights, enrolled students in each course completed a two-question assessment about their relatability to and perceptions of scientists, both before and after completing at least three student-authored Scientist Spotlights assignments. These pre- and postassessments were the same assessment prompts used in previous studies of Scientist Spotlights (Schinske *et al.*, 2015). Face validity and clarity of each of these prompts were checked through informal interviews with undergraduate students at the study institution. In addition, the

TABLE 1. Course-based assessment prompts to evaluate impact of student-authored Scientist Spotlights (adapted from Schinske *et al.*, 2016)

Assessment prompt	Response type	Instructions for students respondents
Relatability prompt	Closed-ended and open-ended	Please reflect on the statement below. Choose and write the number and phrase that reflects your level of agreement. Then, write 200 or more words about your reflections on this statement and your level of agreement. “I know of one or more important scientists to whom I can personally relate.” Strongly disagree Disagree Agree Strongly agree Don’t Know 1 2 3 4 DK
Stereotypes prompt	Open-ended	Please reflect and write 200 or more words about the following prompt: “Based on what you know now, describe the types of people that do science. If possible, refer to specific scientists and what they tell you about the types of people that do science.”

16 student authors of Scientist Spotlights also completed these same pre- and postassessment assignments as part of their LEADS service-learning course to gauge whether the experience of authoring multiple Scientist Spotlights would also influence student authors’ relatability to and perceptions of scientists.

Assessing Students’ Relatability to Scientists before and after Student-Authored Spotlights. To assess students’ relatability to scientists, the following published assessment prompt was employed: “I know of one or more important scientists to whom I can personally relate.” (see Table 1, “Relatability prompt”). While our research team had some concerns about the word “important,” we elected to maintain the assessment wording to be able to compare our findings with those previously published (Schinske *et al.*, 2015, 2016). At the beginning and end of the term, enrolled students and LEADS student authors rated their level of agreement with this statement and submitted written reflections explaining their choices. These responses produced both a closed-ended response that could be easily quantified and an open-ended response that could be checked for student rationales and response validity. Closed-ended responses were gathered on a four-option agreement scale (strongly agree, agree, disagree, strongly disagree), with a fifth “do not know” option. To maximize statistical power, responses were aggregated such that students who selected “strongly agree” or “agree” were combined into an overall “agree” category, while those that selected “strongly disagree,” “disagree,” and “do not know” were combined into an overall “disagree” category. After much deliberation, we chose to include the “do not know” response with the disagree responses, because associated open-ended responses indicated that these students did not know of scientists to whom they could relate.

We analyzed all student responses to the relatability prompt in three ways. First, we compared students’ pre- and postassessment closed-ended responses to the relatability prompt to gauge whether student-authored Scientist Spotlights could have impacts similar to those seen previously with instructor-authored Scientist Spotlights. Second, we compared students’ closed-ended responses to the preassessment relatability prompt across the partner courses, as well as across student demographic subpopulations, to check for pre-existing differences that could influence interpretation of our results. Third, we also explored the reasoning presented in open-ended responses by enrolled students who shifted positively, shifted negatively, or did not shift between their pre- and postassessment responses on the relatability prompt.

Assessing Student Perceptions of Scientists before and after Student-Authored Spotlights. To assess students’ perceptions of and stereotypes about scientists, the following published open-ended assessment prompt was employed: “Based on what you know now, describe the types of people that do science. If possible, refer to specific scientists and what they tell you about the types of people that do science.” (see Table 1, “Stereotypes prompt”; Schinske *et al.*, 2015). This prompt immediately followed the relatability prompt on pre- and postassessments collected from enrolled students and LEADS student authors at the beginning and end of the term.

To qualitatively analyze students’ written responses to the stereotype prompt, we used a modified form of a coding rubric adapted from a previous study on Scientist Spotlights (see Appendix C in the Supplemental Material; Schinske *et al.*, 2015, 2016). Students’ written responses were coded for the presence of one of five categories of previously described scientist descriptions: positive stereotype descriptors, negative stereotype descriptors, and/or non-stereotype descriptors, as well as naming stereotypical scientists or nonstereotypical scientists, each of which is briefly described here. In contrast to the Schinske *et al.* (2016) study, we quantified for the presence of these descriptions, not the number of descriptions in each student response.

Briefly, positive and negative stereotype descriptions were based on Mead and Métraux’s descriptions of scientists, wherein positive stereotype descriptions included descriptions such as “curious, intelligent, and that they make the world a better place” and negative stereotype descriptions included “greedy, competitive, or that they are always working” (Mead and Métraux, 1957). Non-stereotype descriptions were those that went against the stereotypes and included phrases such as “anyone can be a scientist or many types of people can be a scientist.” To categorize stereotypical scientist names, we used a previously identified list of stereotypical scientists (Dikmenli, 2010), which included “Albert Einstein, Isaac Newton, and Charles Darwin.” Nonstereotypical scientist names were considered any named individuals not listed as a stereotypical scientist.

To minimize bias in analyzing and comparing pre- and postassessment evidence, student responses were randomized and anonymized so researchers could not identify when the response was collected. Additionally, each response was independently coded by multiple researchers (M.L.A., J.I.O., C.R.-N., D.C.S., M.J.S., M.D., C.S.W.) using the five codes. Discrepancies were discussed in weekly meetings, and all student responses to the

stereotype prompt were coded to consensus. After coding of these open-ended responses was completed, we compared pre- and postassessment results overall, across the partner courses, and across student demographic subpopulations.

Inclusion Criteria for Participating Enrolled Students and Courses. To be included in the data analyses for the relatability and stereotype prompts, enrolled students in partner courses must have completed both the pre- and postassessment assignments. Additionally, to be included in data analyses, partner courses must have had >40% student participation in both the pre- and postassessments.

Disaggregating Assessment Evidence by Course and Student Demographic Subpopulations. To investigate whether the impact of student-authored Scientist Spotlights varied among students from different demographic backgrounds in the partner courses, we obtained demographic information from the institutional research office using student identification numbers. Specifically, institutional information was obtained for enrolled students' gender identity, racial identity, and Pell Grant status, as a proxy for socioeconomic status, in the partner courses. To maximize statistical power and preserve anonymity, disaggregation of racial groups was only reported for students from populations considered to be underrepresented minorities in science (URM) compared with those who were not. Here, we chose to include students who identified as African American, Black, Latino/a, Native American, Filipino/a, and Pacific Islander as URM and to include white and Asian students as non-URM. Institutional data on students' identification as first-generation college-going, as well as sexual orientation identity, were either incomplete or unavailable and are not reported here.

Department-wide Assessment of Impact of Student-Authored Scientist Spotlights

While the course-based assessment evidence described earlier could be used to probe the proximal influence of student-authored Scientist Spotlight interventions, we also aspired to investigate whether enrolled students would remember and report experiencing this scientist representation on an independent and more distal assessment. To test whether enrolled students would remember their Scientist Spotlight assignments, we examined the results of an independent, annual, department-wide survey at the end of the term that investigated a variety of aspects of students' perceptions of their biology courses. Enrolled students in the partner courses associated with the LEADS service-learning course were a subset of the larger, department-wide student population invited to participate. We were able to compare student responses for biology courses with student-authored Scientist Spotlights and those without. As an incentive to participate, students who participated in the independent, department-wide survey were entered into a raffle in which they could win an assortment of prizes, including gift cards.

On that department-wide survey, three questions were embedded that asked students about the types of scientists they studied in each of their biology courses. Specifically, students were asked to report their agreement that they: 1) studied multiple scientists in that particular biology course, 2) studied multiple scientists of color in that particular biology course, and

3) studied multiple women scientists in that particular biology course. Responses were collected on a four-option agreement scale (strongly agree, agree, disagree, strongly disagree), with a fifth "do not know" option. To maximize statistical power, responses were aggregated such that students who selected "strongly agree" or "agree" were combined into an overall "agree" category, and students who selected "strongly disagree" and "disagree" were combined into an overall "disagree" category. Given the nature of these questions, the "do not know" responses were calculated separately. After overall analysis of these three survey questions, we then disaggregated and compared responses for partner courses that experienced student-authored Scientist Spotlights and for all other biology courses that term that did not complete student-authored Scientist Spotlights.

Comparative Statistical Analyses for Course-Based and Department-wide Assessments

To determine significance, statistical analyses were performed to compare response measures for different subpopulations of students using chi-square analyses. Specifically, to compare pre- and postassessment measures of student relatability to scientists and perceptions of scientists, we determined statistical significance with McNemar analysis. To compare initial, preassessment measures of student relatability to scientists across different courses and different student demographic subpopulations, we determined statistical significance using chi-square analysis. Finally, to compare department-wide students' perceptions of scientist representation between courses with and without student-authored Spotlights, we used chi-square analyses.

RESULTS

These studies of student-authored Scientist Spotlights were designed to investigate the impact of engaging undergraduate students as partners in promoting inclusion and changing scientist representation in biology courses. We first describe the demographic characteristics of the student populations under study: the large population of enrolled students in the partner instructors' biology courses, the LEADS student authors themselves in the service-learning course, and students more broadly who responded to a department-wide student perceptions survey. Then we present results from evidence for research questions 1 and 2 about the impact of student-authored Scientist Spotlights on students' relatability to and perceptions of scientists for enrolled students and all students and disaggregated by student demographic subpopulation. This is followed by research question three analyses of similar assessments from LEADS student authors to gauge the impact of involvement. Finally, we present results for research question 4 from the independent department-wide survey on students' perceptions of scientist representation in courses with and without implementation of Scientist Spotlights.

Student Participant Populations: Characteristics of Enrolled Students in Partner Courses, LEADS Students, and Department-wide Student Survey Respondents
Characteristics of Enrolled Students in Partner Courses That Implemented Student-Authored Scientist Spotlights. Data analyses described here are based on evidence collected from 752 enrolled students who completed both the pre- and

TABLE 2. Characteristics of participating student populations: enrolled students and LEADS student authors

	Women % (n)	URM students % (n)	Pell Grant-eligible students % (n)
All partner courses	70% (525/752)	42% (312/752)	44% (332/752)
Course B	67%	45%	43%
Course C	78%	42%	47%
Course D	70%	23%	47%
Course F	68%	28%	42%
Course G	73%	37%	45%
Course I	73%	50%	52%
Course J	66%	46%	40%
LEADS student authors	75% (12/16)	100% (16/16)	56% (9/16)

postassessments from seven of the eight partner courses that implemented at least three student-authored Scientist Spotlights. Demographic characteristics of these enrolled students are shown in Table 2. Based on our inclusion criteria, evidence from course E and its enrolled students were excluded from analyses due to low overall participation in the postassessment of only 25% (7/28) students. The overall completion rate of both the pre- and postassessments across all enrolled students in partner courses was 53% (752/1410). Student completion rates for both pre- and postassessments in the individual partner courses ranged from 43% to 77%, with the lowest rates generally in the largest courses.

Overall, participating enrolled students in the partner courses were majority women with substantial populations of students from racial groups underrepresented in science (URM) and Pell Grant-eligible students, reflecting lower socioeconomic status (see Table 2). Enrolled students included 70% ($n = 525/752$) who identified as women, ranging from 66% to 78% per course. Across partner courses, 41.5% (312/752) of enrolled students were identified as being from URM subpopulations, ranging from 23% to 50% per course. Finally, 44% (332/752) of these enrolled students were considered Pell Grant eligible, ranging from 40% to 52% across the partner courses.

Characteristics of LEADS Student Authors of Scientist Spotlights. The 16 student authors from the LEADS service-learning course were included in these analyses. This also includes those partnered with course E, as all these students completed both the pre- and postassessments and authored all of their Scientist Spotlights. The LEADS student population was 75% (12/16) women, 100% students from racial groups underrepresented in science (URM), and 56% (9/16) students considered Pell Grant eligible (see Table 2).

Characteristics of Student Respondents in the Department-wide Student Perceptions Survey. On the department-wide survey, there were 1070 responses from 4070 invited students enrolled across all biology courses offered that semester. Because students could submit more than one survey response if they were taking multiple biology courses, we were unable to calculate an accurate response rate or fairly describe the demographic characteristics of respondents. Of the 1070 survey responses, 1) 1064 reported on whether they studied multiple scientists in that particular biology course, 2) 1067 reported on whether they studied multiple scientists of color in that particular biology course, and 3) 1067 reported on whether

they studied multiple women scientists in that particular biology course.

ANALYSES FOR RESEARCH QUESTIONS 1 AND 2

Assessment of Enrolled Students' Relatability to Scientists: Responses to "I Know of One or More Important Scientists to Whom I Can Personally Relate."

To investigate the extent to which enrolled students' relatability to scientists changed after implementation of three or four student-authored Scientist Spotlights, we analyzed enrolled students' responses to the prompt: "I know of one or more important scientists to whom I can personally relate" before and after implementation of student-authored Scientist Spotlights (Table 1, "Relatability prompt"). To test whether shifts in enrolled students' relatability to scientists differed among students of different demographic backgrounds, we disaggregated students' responses to the relatability prompt, based on student characteristics obtained from institutional records. See Appendix D in the Supplemental Material for disaggregation of enrolled students' preassessment responses to the relatability prompt by each partner course.

Students' Relatability to Scientists before and after Implementation of Student-Authored Scientist Spotlights. Approximately half of enrolled students (47%, 350/752) agreed or strongly agreed with this statement *before* experiencing any student-authored Scientist Spotlights compared with *after* Scientist Spotlights, when 76% ($n = 570/752$) of students agreed that they knew of one or more important scientists to whom they could personally relate (Figure 1). This reflects a statistically significant 29% increase from the preassessment evidence ($\chi^2 = 157.14$, $df = 1$, $p < 0.0001$). Similar statistically significant positive shifts in enrolled students' relatability to scientists were seen across all partner courses (Appendix D in the Supplemental Material). Interestingly, there were no significant differences in the preassessment baseline responses to the relatability prompt between women and men ($\chi^2 = 0.48$, $df = 1$, $p = 0.4886$), between URM students and non-URM students ($\chi^2 = 3.28$, $df = 1$, $p = 0.07$), or between Pell Grant-eligible and non-Pell Grant eligible students ($\chi^2 = 0.269$, $df = 1$, $p = 0.6042$).

Enrolled students across all demographic subpopulations examined—women and men, URM students and non-URM students, and Pell Grant-eligible and non-Pell Grant students—demonstrated statistically significant positive shifts in relatability to scientists after implementation of student-authored Scientist Spotlights (Figure 1 and Table 3). Women shifted from

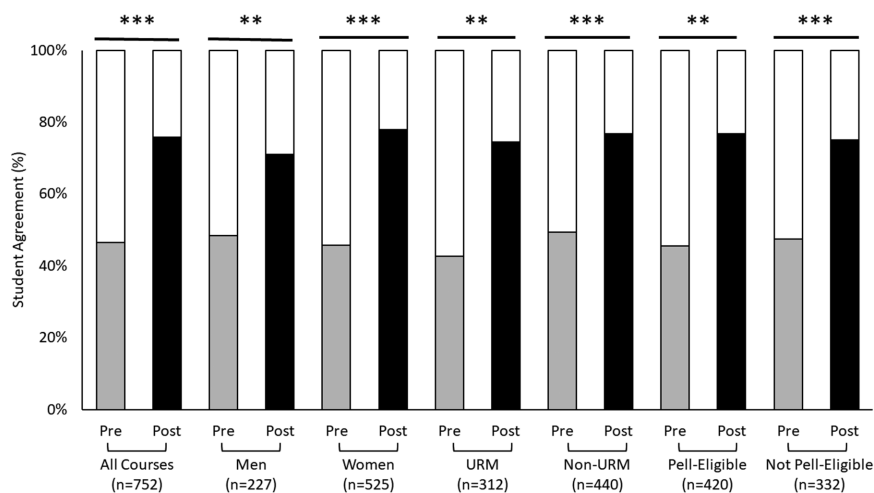


FIGURE 1. Demographic disaggregation of students’ relatability to scientists before and after student-authored Scientist Spotlights across all partner courses. Students’ pre and post agreement with the prompt: “I know of one or more important scientists to whom I can relate” by student demographic characteristics. For pre data: “agree” is shown in gray and “disagree” in white; for post data: “agree” is shown in black and “disagree” in white. Pre–post differences are significant at ** $p < 0.01$ and * $p < 0.001$.**

46% to 78% agreement ($\chi^2 = 12.56, df = 1, p < 0.0001$), and men shifted from 49% to 71% agreement ($\chi^2 = 8.33, df = 1, p = 0.0039$). Students from racial populations underrepresented in the sciences (URM) students, shifted from 43% agreement to 74% agreement ($\chi^2 = 8.89, df = 1, p = 0.0029$), while non-URM students shifted from 49% to 76% ($\chi^2 = 12.25, df = 1, p = 0.0005$). Finally, Pell Grant–eligible students, taken as an indicator of socioeconomic status, shifted from 45% to 77% agreement ($\chi^2 = 8.00, df = 1, p = 0.005$), and non–Pell Grant eligible students shifted from 47% to 75% agreement ($\chi^2 = 13.24, df = 1, p = 0.0003$).

Samples of Enrolled Students’ Written Responses about Their Relatability to Scientists after Implementation of Student-Authored Scientist Spotlights. To understand students’ postassessment reasoning in the open-ended portion of the relatability prompt, we explored the written responses of enrolled students who shifted positively, negatively, or not at all in their agreement with: “I know of one or more important scientists to whom I can personally relate.” In Table 4, we share multiple examples of students’ rationales from among those enrolled students who positively shifted from disagree to agree (36%, 267/752); those who maintained agreement on both

pre- and postassessments (40%, 303/752); and those who did not shift positively (24%, 182/752), either maintaining disagreement on both pre- and postassessments (18%, 138/752) or shifting from agree to disagree (6%, 44/752). We chose not to conduct detailed qualitative analyses of these responses, given the brevity of the responses and no immediately evident emergent themes across student groups. Generally, enrolled students who shifted positively often offered reasoning about their personal connections to the stories of the scientists they studied, sometimes related to gender or racial identity and sometimes related to family experiences, hobbies, or hardships. Enrolled students who maintained agreement on both pre- and postassessments often referred to prior connections to scientists in their personal life or prior experiences studying scientists from diverse backgrounds. Finally, enrolled students who shifted negatively often offered reasoning that they did not share the career passions of the scientists they

studied, had not experienced as many hardships as those scientists, and/or did not share important personal characteristics with these particular individuals.

Scientists Named in Enrolled Students’ Written Responses about Their Relatability to Scientists after Implementation of Student-Authored Scientist Spotlights. While the postassessment relatability prompt did not specifically ask enrolled students to name particular scientists, it was notable that scientists were sometimes named. Unprompted, more than a third of enrolled students (36%, 273/752) named at least one scientist who was featured in a student-authored Scientist Spotlight in their postassessment responses to the relatability prompt. Moreover, half of those named scientists referred to a student-authored Scientist Spotlight that featured an individual who was a graduate student or a postdoctoral scholar (51%, 138/273).

Assessment of Enrolled Students’ Perceptions of Scientists: Responses to “Based on What You Know Now, Describe the Types of People That Do Science.”

To investigate potential shifts in students’ perceptions about scientists, students were asked to respond to the prompt: “Based

TABLE 3. Enrolled students’ shifts in relatability to scientists disaggregated by demographic characteristics

	n	Preassessment agreement % (n)	Postassessment agreement % (n)	p value	Chi-square value
Enrolled students in all partner courses	752	47% (350/752)	76% (570/752)	<0.0001	157
Women	525	46% (240)	78% (409)	0.00004	12.6
Men	227	49% (110)	71% (161)	0.0039	8.33
URM students	312	43% (133)	74% (232)	0.0029	8.89
Non-URM students	440	49% (217)	76% (323)	0.0005	12.3
Pell Grant–eligible students	332	45% (151)	77% (255)	0.0047	8.00
Non–Pell Grant eligible students	420	47% (199)	75% (315)	0.0003	13.2

TABLE 4. Samples of enrolled students' postassessment responses to relatability prompt after implementation of student-authored Scientist Spotlight

Enrolled students who...	% (n)	Sample student evidence from postassessment responses to:
shifted from disagree to agree	36% (267/752)	<p>"I know of one or more important scientists to whom I can personally relate."</p> <ul style="list-style-type: none"> "After taking this course I learned a lot about different scientists which I can relate ... It was nice to read about scientists who are minorities and also women because I never read about them." "I relate to his family background and share some things in common with him academically. I can also relate to [another scientist] because of how she is a woman in science." "I learned that [she] and I have some things in common, things that reflect our journey through school. Both of our parents' divorces and family situations forced us to struggle with finances." "The scientist spotlights have definitely inspired me and showed me a variety of ways of being able to give back to the community with my cultural upbringing."
always agreed	40% (303/752)	<ul style="list-style-type: none"> "I strongly agree with this statement. The one person that I always think about when I think of a scientist is my partner. He runs his own company that tests dietary supplements from Amazon and off the shelves in stores to see if it really has all the vitamins and nutrients that they claim to have." "At the beginning of the semester, I rated that on a scale of 1-4, I would choose a 4 for "strongly agree" to scientists I can personally relate to. Since that rating, nothing has changed, so the rating stays at 4. However, I did discover two new important scientists I could personally to." "[Compared with before] nothing has changed, so the rating stays at 4. However, I did discover two new important scientists I could personally [relate] to. The first new important scientist I can personally relate to is Dr. George M. Langford. Reading his background for one of the scientific spotlights, I was definitely inspired because of all the hardship he had to go through during a tumultuous period in our nation's history." "I agree with this statement. After completing the scientist spotlights throughout the semester I was able to see a variety of scientists. One of the most important points I was able to capture through these exercises was being able to understand that while many difficulties rise when pursuing a degree in the sciences, it is not impossible to persevere."
always disagreed	18% (138/752)	<ul style="list-style-type: none"> "In this course, I studied two Latin American female scientists: one from Argentina and the other from Mexico. Even though they are both Latinas, I do not feel fully represented by them because they are not Salvadoran scientists." "I cannot say I personally relate to any of the scientists we study. Although their work was interesting and I am glad that there are people out there focusing on these things to fix, but none of their passions are the same as mine." "I can't say that I have any relation to any important scientists. I have no drive nor desire to learn about the natural processes that occur in life and feel like my interests are somewhere else unrelated to science." "I do know other scientist, but I don't know if they are considered important to others. I believe every scientist is important, since we all have the potential to change the world. Nevertheless, there are inspiring scientist that I can learn from and that can help inspire me in many ways."
shifted from agree to disagree	6% (44/752)	<ul style="list-style-type: none"> "Although I am a pretty persistent person when it comes to finding the right answer, I do not feel as though I can personally relate to many scientists. I can maybe relate to scientists in the sense that I will go endless hours to find the solution to my problem but I do not think my work ethic is what is [sic] should be." "I don't really consider myself a scientist to be relating myself to one of them because yes, I am interested in going into medicine or any field related, but I wouldn't be a scientist. Also, each scientist had to go through different struggles to get to where they accomplished their dreams, with hardships and hard work." "My reason for this is that the scientists we reviewed in [this class] have gone through adversities that I feel I haven't personally experienced ... Many of these scientists have experienced great adversity in order to have their work recognized. I cannot claim to relate to the adversities that the scientists we learned about had faced and in my opinion, it would be unfair to them to claim to have faced them." "I would have to say that I personally disagree because I feel that I don't really know anyone that I personally would consider a scientist, because I would consider as scientist someone who is officially done with the process of their career and has officially been in there major science career and is making a living of it."

on what you know now, describe the types of people that do science" (Table 1, "Stereotypes prompt") before and after implementation of student-authored Scientist Spotlights. As described in detail in the *Methods*, enrolled students' written responses were analyzed using a coding rubric with five categories, adapted from a previous study on Scientist Spotlights (see

Appendix B in the Supplemental Material; Schinske *et al.*, 2015). Analyses of nonstereotypical descriptors of scientists in enrolled student responses are shown in Figure 2, whereas analyses of *specific named scientists*—either stereotypical scientists or nonstereotypical scientists—are shown in Figure 3. To test whether shifts in perceptions of scientists differed among

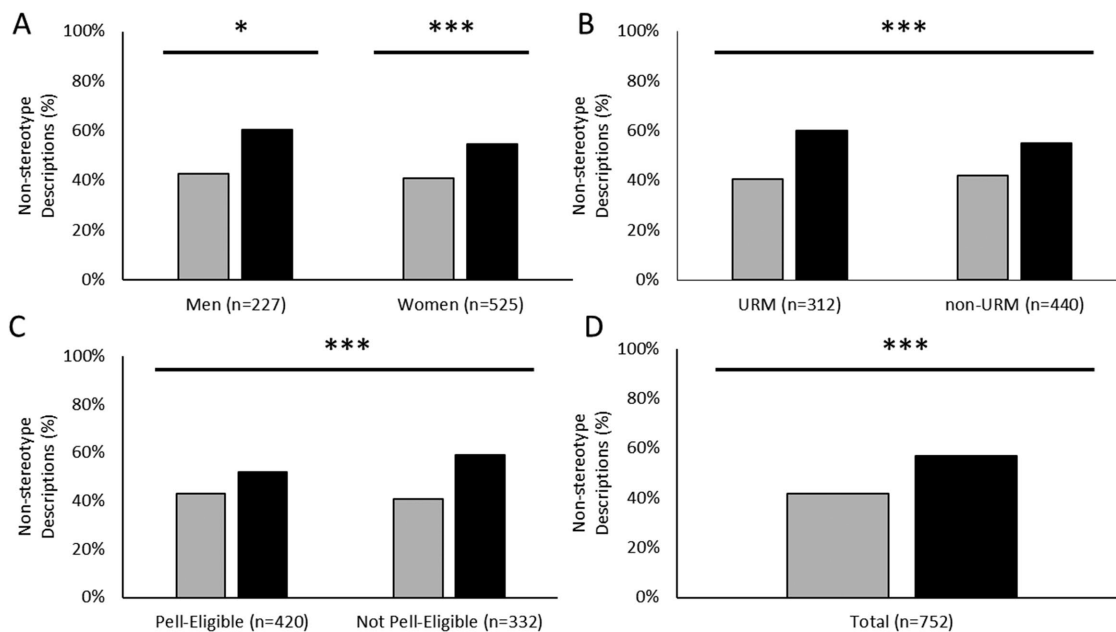


FIGURE 2. Demographic disaggregation of students' non-stereotype scientist descriptions before and after student-authored Scientist Spotlights. Coding of students' pre and post responses to the prompt: "Describe the types of people that do science" for those expressing nonstereotypical descriptors of scientists, disaggregated by (A) gender, (B) URM student status, and (C) Pell Grant-eligible student status. All students are shown in D. Pre data are shown in gray; post data are shown in black. Pre-post differences are significant at $*p < 0.05$ and $***p < 0.001$.

students of different demographic backgrounds, we disaggregated pre- and postassessment analyses of these measures by enrolled students' gender, racial, and socioeconomic characteristics. Additional quantitative details for analyses of these cod-

ing categories are available in Appendices E and F. We present analyses of enrolled students' descriptors of scientists, followed by analyses of specific named scientists, that were offered in their pre- and postassessment responses to this prompt.

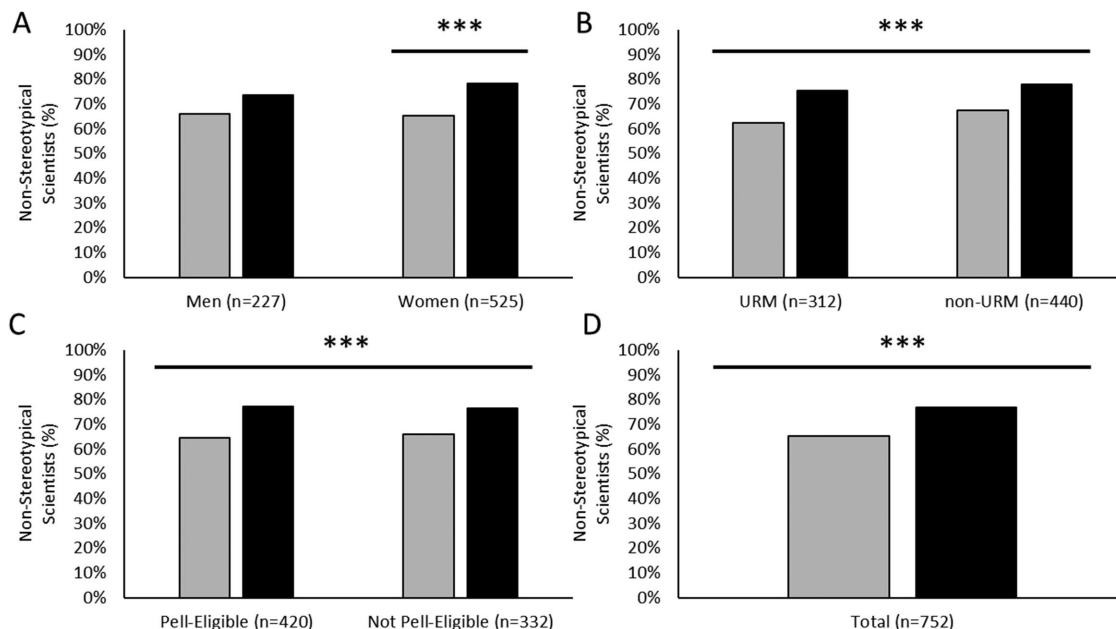


FIGURE 3. Demographic disaggregation of nonstereotypical scientist names offered by students before and after student-authored Scientist Spotlights. Coding of students' pre and post responses to the prompt: "Describe the types of people who do science" for those expressing nonstereotypical scientist names, disaggregated by (A) gender, (B) URM status, (C) Pell Grant-eligible status. All students are shown in D. Pre data are shown in gray; post data are shown in black. Pre-post differences are significant at $***p < 0.001$ for all student subpopulations, except men.

Students' Descriptors of Scientists before and after Implementation of Student-Authored Scientist Spotlights. Before implementation of student-authored Scientist Spotlights, enrolled students in the partner courses at this university had generally positive perceptions of scientists. Terms such as “curious” or “intelligent” were frequently seen in these student responses. Analyses of their postassessment responses demonstrated persistence of these positive perceptions after implementation of student-authored Scientist Spotlights (Appendix E in the Supplemental Material). In contrast, very few enrolled students across all partner courses offered negative stereotype descriptors of scientists, but there was still an approximately 10% decrease in students offering negative stereotype descriptors, such as “working all the time” or “being greedy” (Appendix E in the Supplemental Material). As shown in Figure 2D, 42% (313/752) of enrolled students expressed nonstereotypical descriptors about scientists; commonly offered phrases included language such as “anyone can do science.” In the postassessment, we observed a statistically significant increase in students offering nonstereotypical descriptors of scientists (57%, 429/752), which was an increase from the initial 42% (313/752) of enrolled students expressing such nonstereotypical descriptors ($\chi^2 = 41.02$, $df = 1$, $p < 0.0001$; Figure 2D).

The proportions of enrolled students offering nonstereotypical descriptors of scientists increased significantly across all demographic subpopulations examined after implementation of student-authored Scientist Spotlights, except men (Figure 2). Women shifted from 41% to 55% ($\chi^2 = 39.72$, $df = 1$, $p < 0.0001$), and men shifted from 43% to 61% ($\chi^2 = 4.17$, $df = 1$, $p = 0.0412$). URM students shifted from 41% to 60% ($\chi^2 = 22.08$, $df = 1$, $p < 0.0001$), while non-URM students shifted from 42% to 55% ($\chi^2 = 19.35$, $df = 1$, $p < 0.0001$). Finally, Pell Grant-eligible students shifted from 43% to 52% ($\chi^2 = 25.92$, $df = 1$, $p < 0.0001$), and non-Pell Grant eligible students shifted from 41% to 59% ($\chi^2 = 17.36$, $df = 1$, $p < 0.0001$). While the shift for men did not reach significance level, we anticipate that this was likely because men represented the smallest subpopulation of enrolled students. Interestingly, similar to the analyses for the reliability prompt described earlier, there were no major differences between disaggregated demographics on any preassessment measures related to the stereotypes prompt (Appendix F in the Supplemental Material).

Enrolled Students Named Stereotypical and Nonstereotypical Scientists before and after Implementation of Student-Authored Scientist Spotlights. Before implementation of student-authored Scientist Spotlights, we also examined the proportion of enrolled students who offered the names of stereotypical and nonstereotypical scientists in their written responses to the preassessment stereotypes prompt (Figure 3 and Appendix E in the Supplemental Material). Approximately 65% (492/752) of enrolled students offered one or more nonstereotypical scientist names (Figure 3D) before implementation of Scientist Spotlights. Perhaps related to course curriculum at the institution, James Watson and Francis Crick were the most frequently offered stereotypical scientist names, while Rosalind Franklin was the most commonly offered nonstereotypical scientist name. Enrolled students shifted away from naming stereotypical scientists and toward naming nonstereotypical scientists in their postassessment responses (Figure 3

and Appendix E in the Supplemental Material). While already high initially, the proportion of enrolled students offering nonstereotypical scientist names increased significantly to 77% (579/752) from the initial 65% (492/752) after implementation of student-authored Scientist Spotlights ($\chi^2 = 27.80$, $df = 1$, $p < 0.0001$; Figure 3). Students from all demographic subpopulations examined also demonstrated significant increases toward offering nonstereotypical scientist names after implementation of student-authored Scientist Spotlights, except men. Women shifted from 65% to 78% ($\chi^2 = 26.30$, $df = 1$, $p < 0.0001$), and men shifted from 66% to 74% ($\chi^2 = 3.40$, $df = 1$, $p = 0.0652$). URM students shifted from 63% to 75% ($\chi^2 = 14.55$, $df = 1$, $p = 0.0001$), while non-URM students shifted from 68% to 78% ($\chi^2 = 13.56$, $df = 1$, $p = 0.0002$). Finally, Pell Grant-eligible students shifted from 65% to 77% ($\chi^2 = 13.67$, $df = 1$, $p = 0.0002$), and non-Pell Grant eligible students shifted from 66% to 77% ($\chi^2 = 14.36$, $df = 1$, $p = 0.0002$). Again, we anticipate that the lack of statistical significance for men may reflect that this is the smallest subpopulation of enrolled students.

ANALYSES FOR RESEARCH QUESTION 3

Analyses of LEADS Student Authors' Reliability to and Perceptions of Scientists

To gauge the impact of authoring—rather than experiencing—Scientist Spotlights, we analyzed the responses of the 16 LEADS student authors in the service-learning course on both the reliability prompt and the stereotypes prompt. These responses were completed before and after authoring four Scientist Spotlights over the term (Figure 4).

LEADS Students' Reliability to Scientists before and after Authoring Scientist Spotlights. As shown in Figure 4A, LEADS students significantly increased their reliability to scientists over the course of the term. Initially, only 12.5% (2/16) of LEADS students agreed or strongly agreed with the statement “I know of one or more important scientists to whom I can personally relate” before authoring any Scientist Spotlights. Proportionally, this was a lower level of agreement than enrolled students across all partner courses (Figure 1). After authoring four Scientist Spotlights in the context of the LEADS service-learning course, 100% of LEADS students shifted to agreeing with this statement. Despite the low sample size ($n = 16$), this shift in LEADS students' reliability to scientists was statistically significant ($\chi^2 = 15$, $df = 1$, $p = 0.036$).

LEADS Students' Perceptions of Scientists before and after Authoring Scientist Spotlights. As shown in Figure 4B and C, there was a decrease in the proportion of LEADS students expressing negative stereotypical descriptors and an increase in those expressing nonstereotypical perceptions of scientists in their postassessment responses. Initially, only 31% (5/16) of LEADS students offered positive stereotype descriptors of scientists, whereas 63% (10/16) of LEADS offered either negative stereotype or nonstereotypical descriptors of scientists in their preassessment responses. After authoring four Scientist Spotlights, a few more LEADS students (44%, 7/16) offered positive stereotype descriptors, but the largest shifts were that only a single LEADS student (1/16) offered a negative stereotypical descriptor of scientists and all but one LEADS students (15/16

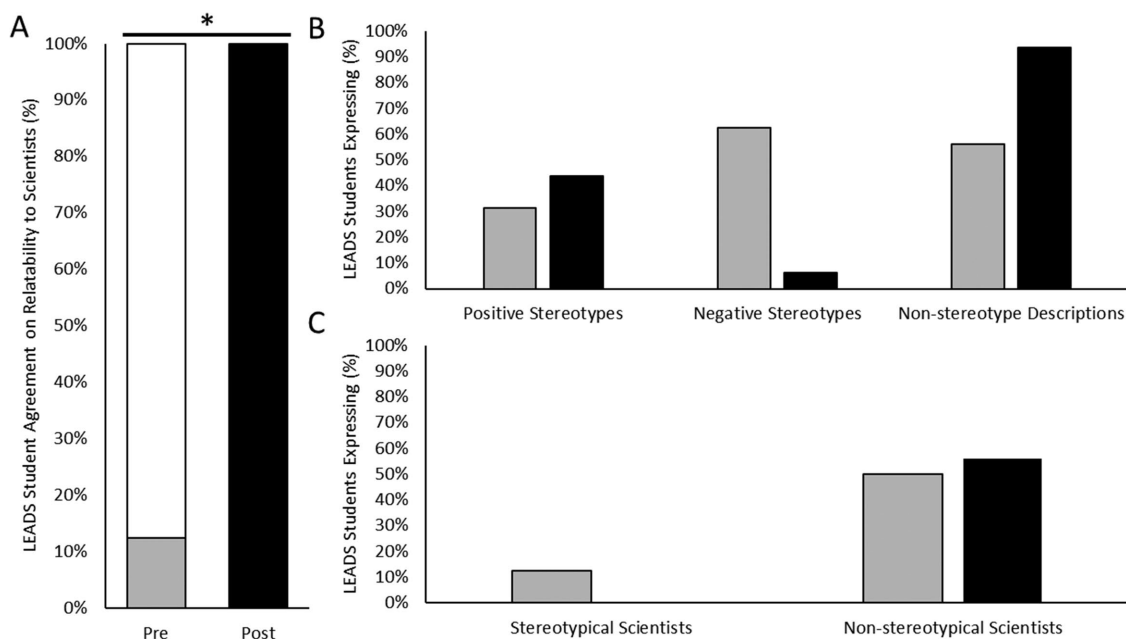


FIGURE 4. Analyses of LEADS student authors' assessment responses before and after authoring Scientist Spotlights themselves. LEADS students' pre and post agreement to the prompt: "I know of one or more important scientists to whom I can relate." For pre data, "agree" is shown in gray and "disagree" is in white; for post data, "agree" is shown in black, and there was no disagreement (A). LEADS students' pre and post responses to the prompt: "Describe the types of people who do science" for those offering positive stereotype descriptors, negative stereotype descriptors, or nonstereotypical descriptors of scientists (B) and those offering names of stereotypical or nonstereotypical scientists (C) before and after authoring Scientist Spotlights themselves. Pre data are shown in gray; post data are shown in black. $n = 16$ for all panels. Pre–post differences are significant at $*p < 0.05$ for the reliability prompt.

offered nonstereotypical descriptors of scientists in their postassessment responses. With respect to inclusion of named scientists, many LEADS students offered names of nonstereotypical scientists before and after authoring Scientist Spotlights, and only two LEADS students included any stereotypical scientist names in any of their assessment responses (see Figure 4C).

ANALYSES FOR RESEARCH QUESTION 4 Independent, Department-wide Survey of Biology Students' Perceptions of Scientists Studied as Part of Their Biology Course Curriculum at End of Term

To test whether enrolled students in LEADS partner courses would remember their Scientist Spotlight assignments at the end of the term, we examined the results of an independent, annual, department-wide survey that investigated a variety of aspects of students' perceptions of their biology courses. Students in partner courses associated with the LEADS service-learning course ($n = 1382$ total, 752 of whom completed both the pre- and postassessments) were a subset of the larger, department-wide student population invited to participate ($n = 4070$ total invited to survey). As such, we were able to compare student responses for biology courses that had implemented student-authored Scientist Spotlights and those that had not.

Department-wide Student Perceptions of Studying Multiple Scientists in Biology Courses with or without Implementation of Student-Authored Scientist Spotlights. As shown in Figure 5 and Table 5, significantly more students in LEADS partner courses (92%, 254/278) reported studying multiple scientists in their biology course compared with less than half of the

students (45%, 352/791) whose courses did not experience student-authored Scientist Spotlights ($\chi^2 = 187$, $df = 1$, $p < 0.0001$).

Department-wide Student Perceptions of Studying Multiple Scientists of Color in Courses with or without Implementation of Student-Authored Scientist Spotlights. Similarly, significantly more students in LEADS partner courses (83%, 230/278) reported studying multiple scientists of color in their biology course compared with only a quarter of students (23%, 183/789) whose courses did not experience student-authored Scientist Spotlights ($\chi^2 = 308$, $df = 1$, $p < 0.0001$).

Department-wide Student Perceptions of Studying Multiple Women Scientists in Courses with or without Implementation of Student-Authored Scientist Spotlights. Finally, significantly more students in LEADS partner courses (89%, 245/276) reported studying multiple women scientists in their biology courses compared with only a third of students (35%, 259/791) whose courses did not experience student-authored Scientist Spotlights ($\chi^2 = 258$, $df = 1$, $p < 0.0001$).

DISCUSSION

We investigated whether student-authored Scientist Spotlights have effects similar to those authored by instructors, while also engaging students in reform efforts through a service-learning course. In the following sections, we explore key findings that emerged from these studies that addressed our research questions. First, we explore the discovery that student-authored Scientist Spotlights produced effects similar to those seen

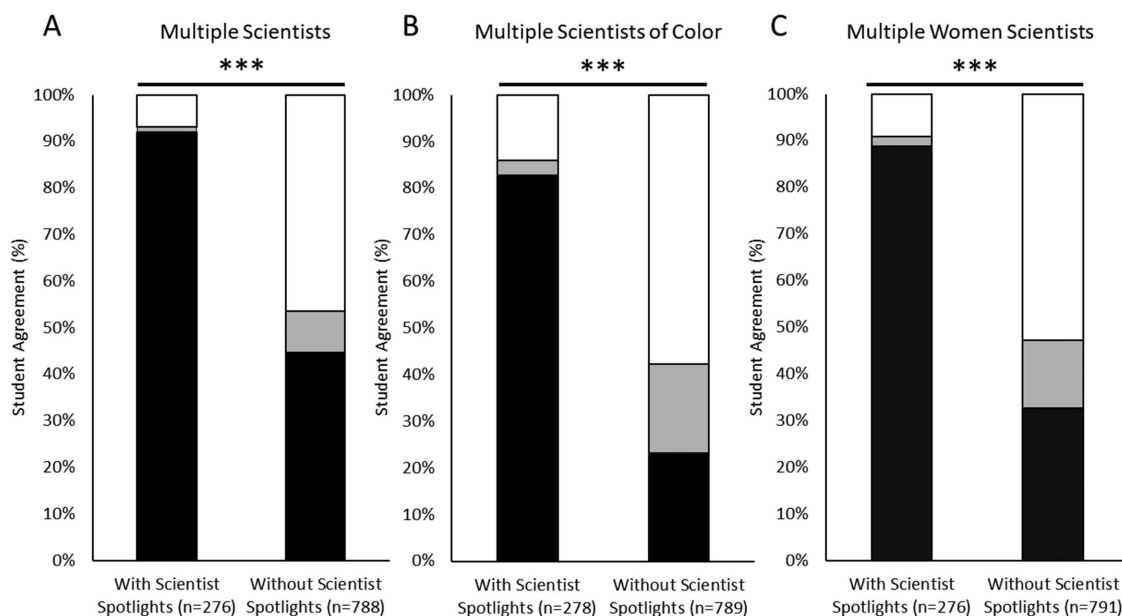


FIGURE 5. Independent department-wide survey of students’ agreement that they studied multiple scientists, multiple scientists of color, or multiple women scientists in biology courses. Responses from students in LEADS partner courses (with Scientist Spotlights, $n = 278$) compared with departmental students in non-LEADS courses (without Scientist Spotlights, $n = 792$) indicating level of agreement to (A) “I have studied multiple scientists in this course.” (B) “I have studied multiple scientists of color in this course.” (C) “I have studied multiple women scientists in this course.” “Agree” is shown in black, “not sure” in gray, and “disagree” in white. Differences are significant at $*p < 0.001$.**

previously with instructor-authored Scientist Spotlights and did so with as few as three student-authored Scientist Spotlights during a term. Second, we consider the observation that student-authored Scientist Spotlights shifted peers’ relatability to and perceptions of scientists, regardless of the students’ own demographic characteristics. Third, we explore the implication that authoring Scientist Spotlights is a new and effective way itself to increase students’ relatability to scientists. Fourth, we explore implications of differences in perceptions of scientist representation found among students in courses with and without student-authored Scientist Spotlights. Finally, we assert that these results, taken together, suggest that engaging students as partners in reform is a promising approach to promoting inclusion and addressing representation in science courses.

As Few as Three Student-Authored Scientist Spotlights Shifted Students’ Relatability to and Perceptions of Scientists

While previous studies have documented that Scientist Spotlights can positively and significantly shift students’ relatability

to and perceptions of scientists (e.g., Schinske *et al.*, 2016; Brandt *et al.*, 2020), the data presented here expand our understanding of this inclusive teaching intervention in several ways. First, we discovered that student-authored Scientist Spotlights produced significant shifts in peers’ perceptions of scientists, comparable to those seen with instructor-authored Scientist Spotlights, which is novel. Further, as few as three student-authored Scientist Spotlight assignments implemented over a term produced these observed shifts. This suggests that even fewer inclusive curricular interventions than those previously tested—nine to 10 instructor-authored Scientist Spotlights over a term—may yield widespread positive benefits for students (Schinske *et al.* 2016; Yonas *et al.*, 2020). We chose to investigate the impacts of implementing three to four student-authored Spotlights for pragmatic reasons. We anticipated that that was a feasible number of Scientist Spotlights for undergraduate students to author in a term, as well as for partner instructors to implement in this coordinated, large-scale effort. Our results suggest that integrating fewer Scientist Spotlights at other institutions may similarly have positive outcomes, which could

TABLE 5. Department-wide assessment of scientist representation in courses with and without implementation of student-authored Scientist Spotlights

	<i>n</i>	Courses with student-authored Scientist Spotlights agreement (%)	Courses without student-authored Scientist Spotlights agreement (%)	<i>p</i> value	Chi-square value
I have studied multiple scientists in this course.	1064	92% (254/276)	45% (352/788)	<0.0001	187
I have studied multiple scientists of color in this course.	1067	83% (230/278)	23% (183/789)	<0.0001	308
I have studied multiple women scientists in this course.	1067	89% (245/276)	33% (259/791)	<0.0001	258

enable a broader array of instructors to adopt this inclusive teaching intervention and diversify the representation of scientists in science courses. Previous studies of instructor-authored Scientist Spotlights may also have been able to achieve similar shifts with fewer assignments, and future studies could investigate that possibility.

Interestingly, it is possible that students authoring the Scientist Spotlights in our study may have impacted the observed effects occurring with fewer assignments. Unlike prior efforts and other Scientist Spotlight intervention studies, each of the student-authored Scientist Spotlights investigated here included a picture and brief biography of the student author at the end of the assignment (see *Methods* and Appendix B in the Supplemental Material), often including a note about why the student had chosen that particular scientist. As a reminder, all of our student authors identified as students of color majoring in biology. This additional author information may have served as a second example of a counter-stereotypical individual pursuing interests within the same assignment, as well as an opportunity for enrolled students to see themselves in the student author (Markus and Nurius, 1986). While investigation of the influence of this biographical information about student authors themselves was beyond the scope of this initial study, these “About the Author” modifications to the original structure of Scientist Spotlights may have contributed to the study outcomes and would be an interesting subject of future research.

Additionally, there were other differences between this study site and previous study sites that may have influenced our findings. The current study institution is an urban, minority-serving, Hispanic-serving, and master’s-granting institution with a rich history of efforts toward inclusion in science, which may have had synergistic influences in this study. The current comprehensive university study site is distinct from previous institutions where instructor-authored Scientist Spotlights have been investigated, which have included a community college and a research-intensive institution. Further, the context of the current study was within a biology department in which the majority of instructors had previously participated in extensive professional development in evidence-based and inclusive teaching (Owens *et al.*, 2017, 2018; Harrison *et al.*, 2019). As such, there may have been other aspects of the study site—perhaps departmental climate or existing classroom practices not measured here—that somehow maximized the impact of implementing either three or four student-authored Scientist Spotlight assignments. As discussed in the original description of Scientist Spotlights, one wonders what type of noncontent classroom language—namely Instructor Talk (Seidel *et al.*, 2015; Schinske *et al.*, 2016; Harrison *et al.*, 2019)—was used by partner instructors as they implemented these curricular interventions and how that language may (or may not) have influenced the effectiveness of these student-authored Scientist Spotlight assignments.

Student-Authored Scientist Spotlights Impacted Students across All Demographic Subpopulations

While we predicted that women, students from racial populations underrepresented in science, and Pell Grant-eligible students would initially have lower relatability to scientists and then show larger positive shifts after implementation of student-authored Scientist Spotlights, this was not the case. Like

previous studies of instructor-authored Scientist Spotlights, students whose reported personal characteristics did not reflect traditional stereotypes of scientists did indeed benefit from student-authored Scientist Spotlights, but so did students from all demographic characteristics studied. In some previous studies incorporating Scientist Spotlights into science curricula, students from racial populations underrepresented in science not only had lower initial measures of relatability to and perceptions of scientists, but also had larger positive shifts in these measures after implementation of Scientist Spotlight assignments compared with white peers (Schinske *et al.*, 2016). Additionally, prior studies have reported that students’ reflections on what they learned from Scientist Spotlights often included references to the importance of common personal characteristics—gender, racial, religious, sexual orientation, socioeconomic, and/or other characteristics—of the scientists being studied (Yonas *et al.*, 2020).

However, our results showed that men, students from white and Asian racial backgrounds, and students who were not Pell Grant-eligible had similar baseline measures and similar shifts in their perceptions of scientists, regardless of these identity characteristics. These data suggest that student-authored Scientist Spotlights—at least in this study context—were not only valuable for those who may be underrepresented in the sciences but beneficial for all students. In fact, raising awareness among students who often see aspects of themselves represented in science may be essential to fostering widespread reduction in scientist stereotypes (Warikoo and de Novais, 2015). Relatedly, it was striking that more than half of scientists remembered in students’ post-Scientist Spotlight reflections were graduate students or postdoctoral scholars, perhaps because these individuals were relatable near peers. While we anticipated that Scientist Spotlights would provide access to rare role models for underrepresented students, it is promising that student-authored Scientist Spotlights—and perhaps Scientist Spotlights more generally—may significantly influence the views of men, white students, and higher socioeconomic status students, as well. Beyond investigating Scientist Spotlights, our findings also suggest future research is needed to understand differences in baseline measures of scientist relatability and stereotypes across different study contexts. For example, are the similarities in baseline measures across all student demographic groups in this study unique to this particular department, this particular institution, this region of the country, or due to some other variable? Future studies should interrogate the origins of differences and similarities among baseline relatability and stereotypes measures across student demographic groups in different study contexts.

Authoring Scientist Spotlights Shifted Students’ Relatability to Scientists

Strikingly, those undergraduate students whose primary involvement was to author Scientist Spotlights over the course of the term in the LEADS service-learning course also showed shifts on scientist relatability and stereotypes measures. Authoring Scientist Spotlights—at least in the context of a service-learning course—was effective in increasing students’ relatability to scientists, decreasing negative scientist stereotypes, and moving students even more toward nonstereotypical views of scientists, perhaps as a result of their sense of autonomy

in acting as developers of their peers' biology course curriculum ("Building Autonomous Learners," 2016). A key innovation of this current study of student-authored Scientist Spotlights was to center the voices of students, giving them not only the power of choosing the scientists represented in the Scientist Spotlights they developed, but also control over which aspects of the scientists' personal and professional stories were highlighted. These results suggest that *authoring* Scientist Spotlights may be an additional science education reform approach to promoting inclusion that leverages students' authentic perspectives and unique community cultural assets (Yosso, 2005). Student authorship of curricular interventions may increase the likelihood that the Scientist Spotlights produced will resonate with their peers (e.g., Moore *et al.*, 2011). Additionally, engaging students themselves as authors of Scientist Spotlights has the potential to cultivate student agency and skill in seeking out possible selves and potential role models themselves (Schinske *et al.*, 2015). Other research suggests that, when students take charge and are involved with their research and education, they feel empowered and more interested in pursuing a scientific research career (Thoman *et al.*, 2015). While not investigated here, one wonders what additional benefits accrued to these student authors and how their involvement in these efforts may influence their long-term commitment to actively promoting inclusion in science and other professional environments. Future research could investigate whether student engagement in efforts such as authoring Scientist Spotlights, especially for students from communities historically marginalized by science, might promote retention in science, higher graduation rates, and/or other longer-term influences on professional success.

Importantly, situating the development of student-authored Scientist Spotlights in the LEADS service-learning course may have been key to the positive impacts observed for student authors in this study. Prior research on the impact of service learning has shown that these courses can positively influence the construction of students' identities, such as their relation to self, their relationship with others, and an openness to new ideas (Jones and Abes, 2004). As one example, computer science service learning both encouraged younger, precollege students in computer science and also provided undergraduate students with leadership opportunities and improved their own attitudes toward computer science (Dahlberg *et al.*, 2010). Situating this student-authored Scientist Spotlights effort in a service-learning course that counted as a biology course elective was key to providing students with authentic incentives that propelled them toward graduation, in addition to ongoing support in the Scientist Spotlight development process in collaborations with partner instructors. Additionally, to maximize the possible gains of our service-learning course for the students involved, we purposefully grounded all course activities in an asset-based framework that consistently acknowledged students' unique knowledge of peers and their communities' cultural wealth (Yosso, 2005), avoiding deficit-based models so often asserted for students of color in science (Mitchell *et al.*, 2012). This shifts the curriculum and pedagogy toward more inclusive and evidence-based approaches. Further situating these reform efforts in the context of a service-learning course was a strategy to institutionalize an ongoing mechanism by which students and instructors could collaborate each semester

in changing biology. While student authorship of Scientist Spotlights produced benefits in this initial study, further research is needed to investigate whether similar benefits could be replicated in other institutional contexts or achieved in the absence of a service-learning course support structure.

Beginning to Probe Distal Influences of Student-Authored Scientist Spotlight Interventions

The long-term impacts of implementing student-authored or instructor-authored Scientist Spotlights continues to be unclear. Here we examined whether we could detect differences in students' perceptions of scientist representation in their courses on an independent and somewhat more distal assessment measure, namely an end-of-term, department-wide student survey. While course-based assessments suggested an immediate impact of Scientist Spotlights, it is even more promising that students evidenced enduring memories of these curricular interventions on the non-course based, end-of-term, department-wide assessments. One might have hypothesized that the impact of Scientist Spotlights would not have been measurable beyond the course context or without specific cuing. However, the integration of this small number of curricular assignments intended to explicitly message the importance of diversity and inclusion in science appears to have made a strong impression. Significantly higher proportions of students in courses that implemented student-authored Scientist Spotlights reported studying multiple scientists, scientists of color, and women scientists as compared with students in courses without Scientist Spotlights. Given the implication that Scientist Spotlights—whether student-authored or instructor-authored—may have a longer-term influence on students, there are many opportunities for future lines of research on the long-term and longitudinal impact of Scientist Spotlights. How, if at all, do students remember these curricular interventions years later? To what extent is integration of Scientist Spotlights in undergraduate curricula associated with increased retention and graduation rates? When will it become regularly expected by students that they will study multiple scientists, in particular multiple women scientists and scientists of color, in every single biology and science course they take? Small curricular interventions have been previously shown to have large effects on students (e.g., Miyake *et al.*, 2010), and a host of future research studies could investigate the longer-term and more distal impacts of student-authored Scientist Spotlights.

Engaging Students as Partners in Undergraduate Science Education Reform

Given the results of our studies, we assert that involving students themselves as active change agents in improving college and university science education is an underappreciated and underleveraged approach (Cook-Sather *et al.*, 2018; Matthews *et al.*, 2018, 2019). There is a persistent lack of diversification of STEM faculty and instructors in higher education, and the projected timelines to affect change are bleak (Gibbs *et al.*, 2016). As such, the current STEM instructor population has limited cultural understanding of the challenges faced by their students, who often have faced dramatically different life circumstances than instructors themselves have experienced. Involving students from diverse backgrounds—in particular students from marginalized populations—as co-developers of

curricular interventions and change efforts can center authentic student perspectives and leverage valuable student cultural assets for the betterment of undergraduate science education (Yosso, 2005). Students bring perspectives that connect their science learning to their linguistic skills, social networks, familial values, and personal and professional aspirations. Moreover, purposefully involving students from groups that have been historically excluded from higher education has the potential to bring novel insights from individuals who have had to navigate systems not designed for them and who have developed strategies to resist structural oppression.

A critique of engaging students as change agents in reform is that these students should not be burdened with the work of reforming systems that should rather be serving them. However, in our own context, we have experienced enthusiasm from students who want to be involved in promoting social justice in their educational setting, both for their own benefit and for the benefit of students coming through the system after them. Thoughtful structuring of students' involvement in science education reform efforts can minimize burden and maximize benefit. For example, structuring student partnership within the context of a meaningful, high credit-bearing biology course that counts toward the university's major requirements can propel, rather than delay, students toward graduation. Similarly, honoring students' scholarly efforts through their coauthorship on a publication like this one not only acknowledges their role as key partners in the work, but also introduces them to the processes of academic publishing. Further, the original service-learning course that was the context for this study has evolved to include learning outcomes and course assignments that are explicitly intended to build students' leadership, advocacy, and facilitation skills. Specifically, these changes have been made to maximize benefit and minimize burden with the goal of fledging change agents into the professional worlds of science and medicine who can continue to advocate for inclusion, representation, and social justice long after their college years are complete (J.N.S., personal observation).

Limitations of the Study and Future Directions

It is important to note that there are several limitations to the present study. This was a large study that included many different biology courses, and the authors were not present in any of the class sessions to note whether faculty discussed any scientists at length outside of the Scientist Spotlights. This would impact the scientist names students mention while discussing the scientists that they related to or knew. We asked faculty to give the assessments as early as possible in the semester, but that was not always possible in some courses, so the timing of the assessments might have skewed the initial baseline results if those faculty discussed any scientists in their courses in those beginning weeks. We predict that this may have affected course B, as there were many specific references to "Watson and Crick," suggesting that students might have learned about those scientists in a homework assignment. Additionally, as mentioned earlier, the institution involved has participated in previous department-wide professional development efforts for faculty to improve their teaching and include more equitable teaching practices. One of the courses involved in our study has specifically undergone extensive curricular reform to improve the out-

comes of our biology students, and this could explain the high pre values when students were asked to reflect on whether they knew a scientist they could relate to or the types of people who do science.

Additionally, the current study raises multiple questions that merit future lines of inquiry. In particular, it is unclear how student-authored Scientist Spotlights may qualitatively differ from instructor-authored Scientist Spotlights. While beyond the scope of this initial investigation, future research might probe how those individuals chosen by undergraduate students to be spotlighted may differ—in age, cultural background, position type, institution type, or other characteristics—from those individuals chosen by instructors. Further, the specific influence of the added "About the Author" section of student-authored Scientist Spotlights is unknown and may have contributed to the current results in unexamined ways. Finally, there are a host of research questions about students' and instructors' experiences in their partnerships through the LEADS service-learning course. The extent to which authoring Scientist Spotlights had additional impacts beyond the student authors' shifts in relatability or and perceptions to scientists—perhaps their impacts on self-efficacy, sense of belonging, and/or sense of agency—is unknown and could be investigated in future studies.

IN CONCLUSION

Scientist Spotlights—curricular materials that employ the personal and professional stories of scientists from diverse backgrounds to address course content—have previously been shown to positively influence undergraduate students' relatability to and perceptions of scientists. Results presented here revealed that exposure to three or four student-authored Scientist Spotlights significantly shifted peers' perceptions of scientists in all partner courses. Additionally, student-authored Scientist Spotlights shifted peers' relatability to scientists regardless of their demographic characteristics. Importantly, student authors themselves showed increases in their relatability to scientists. Significant differences were evident in students' perceptions of scientist representation between courses with and without student-authored Scientist Spotlights in department-wide assessment measures. Taken together, these results suggest that engaging students as authors of inclusive curricular materials and partners in reform is a promising approach to promoting inclusion and addressing representation in science.

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