Fostering Inclusion through an Inter-institutional, Community-engaged, Course- based Undergraduate Research Experience

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Abstract:

Creation of an inclusive environment requires a culture of equity, justice, value and respect for diverse backgrounds, and opportunities for students to engage with communities while addressing issues in science and society. These tasks are particularly challenging for institutions lacking a diverse population. Here, we demonstrate evidence of a successful model for creating an inclusive environment in an interinstitutional course between a large, public, historically black institution and a small, private, primarily white institution. Because many individuals from underrepresented minority groups tend to value communal goals of working together and helping their communities, we incorporated two high-impact practices of community-engaged learning and course-based undergraduate research experiences (CUREs) focused on health disparities research in neighboring communities. Although the research projects varied each semester, they were linked by their impact on and engagement with the community. Students practiced cultural competency skills in both small group projects within the class and engagement activities in the community. We measured the efficacy of CURE components (novel authentic research, scientific process skills, iteration, collaboration, and broader impact) through a combination of direct and indirect assessments, quantitative and qualitative analysis. More than simply scientific skills, students from both institutions developed lasting interest in working with diverse populations as well as respecting and valuing different backgrounds. This inclusive environment, combined with increased interest in research, suggests that this course could potentially serve as a model for interinstitutional collaborations in creating inclusive environments that support the future success of diverse students, eventually changing the STEM research culture.

Keywords: higher education | undergraduate research | STEM | diversity and inclusion

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Fostering Inclusion through an Interinstitutional, Community-Engaged, Course-Based Undergraduate Research Experience†

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Creation of an inclusive environment requires a culture of equity, justice, value and respect for diverse backgrounds, and opportunities for students to engage with communities while addressing issues in science and society. These tasks are particularly challenging for institutions lacking a diverse population. Here, we demonstrate evidence of a successful model for creating an inclusive environment in an interinstitutional course between a large, public, historically black institution and a small, private, primarily white institution. Because many individuals from underrepresented minority groups tend to value communal goals of working together and helping their communities, we incorporated two high-impact practices of community-engaged learning and course-based undergraduate research experiences (CUREs) focused on health disparities research in neighboring communities. Although the research projects varied each semester, they were linked by their impact on and engagement with the community. Students practiced cultural competency skills in both small group projects within the class and engagement activities in the community. We measured the efficacy of CURE components (novel authentic research, scientific process skills, iteration, collaboration, and broader impact) through a combination of direct and indirect assessments, quantitative and qualitative analysis. More than simply scientific skills, students from both institutions developed lasting interest in working with diverse populations as well as respecting and valuing different backgrounds. This inclusive environment, combined with increased interest in research, suggests that this course could potentially serve as a model for interinstitutional collaborations in creating inclusive environments that support the future success of diverse students, eventually changing the STEM research culture.

INTRODUCTION

In an increasingly global society, many of our challenges cross political and cultural boundaries, requiring a diverse workforce with varied perspectives that are critical for problem solving. However, U.S. health professions and scientific research communities do not reflect the country's diverse demographics, which limits the pool of talented scientists and fails to foster questions generated by unique perspectives (1–4). Data from the National Center for Science and Engineering Statistics illustrate this disparity in STEM undergraduate enrollment, acquisition of undergraduate and graduate degrees, and employment in STEM careers (4). In an effort to reach a broader, more diverse student population by reducing equity and capacity limitations for undergraduate research, course-based undergraduate research experiences (CUREs) were designed. These embed

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scientific practices, novel discovery, broad relevance, collaboration, and iteration into the classroom (5–7) through Freire's critical pedagogy framework and a constructivist learning approach (8). Constructivist learning ascribes to a transformational pedagogical framework that values the relationship between the teacher and learner as a partnership. The interaction shifts from didactic instruction via a position of "telling-listening" (9) to a learner-centered process (10) where "the teacher cannot think for her students nor can she impose her thoughts on them" (8). Knowledge is collectively constructed and shared through engagement with one another (11). To this end, numerous studies have documented cognitive, psychosocial, behavioral, and retention gains in CURE students, regardless of underrepresented minority (URM) status (12–15).

Although these efforts increase the diversity in the classroom and laboratory, additional forces impede the retention and performance of URM groups in STEM (16–18). One barrier involves the misperception of science as an isolated discipline addressing questions of little interest outside the scientific community. Studies have shown that URM students often value communal goals of collaboration and helping people as important factors in their educational and career objectives and are, therefore, dissuaded from STEM careers (19–23). One potential solution involves the practice of community-engaged learning (CEL), where students participate in community-centered projects prompting them to reflect on the broader economic, social, and political contexts of a problem. This approach emphasizes the communal goals of scientific pursuits, exposing students to the interdisciplinary and collaborative nature of science, which may positivity impact the recruitment and retention of URM students. This dual approach also reflects the core competencies outlined in the *2011 AAAS Vision and Change* report, including application of the scientific process, use of quantitative reasoning, communication and collaboration between disciplines, and exploration within a social context (24). At the institutional level, the collaborative partnerships generated with these projects can strengthen the relationship between higher education institutions and the surrounding communities through sustained collaboration and action.

Another barrier to the retention of URM students in STEM fields is the degree of diversity reflected in the classroom and lack of inclusive practices. Although numerous studies have provided evidence for the educational value of multicultural classroom experiences, successful implementation involves attention to the teaching philosophy, curriculum, and pedagogies that create a safe and inclusive classroom (25–28). Steps toward alleviating this concern involve the intentional training of students to value and respect diverse individuals, promoting equity and justice in the STEM environment and engaging students in projects that address relevant issues outside of the classroom (21, 23). Learning from others fosters a deeper level of inclusiveness, exposing students to a wide range of perspectives and experiences that provide the substrate for the generation of complex and inclusive thought processes (29). Ultimately, culturally relevant pedagogies must respect deep cultural values related to how decisions are made, how communication occurs, and how learning is valued (30).

In the current study we hypothesized that combining these high-impact practices (CEL and CURE) within a collaborative, interinstitutional course which engaged students in community-based participatory research (CBPR) focused on health disparities in immigrant/refugee communities would create an inclusive environment. This framework was built upon the theoretical groundwork of constructivist learning as a partnership between teacher and learners and focused on real-world scenarios (8, 9, 31–33) (Appendix 1). Most CUREs are developed around workflows that can be repeated each year, e.g., HHMI SEA-PHAGES (34), Small World initiative (35), PARE (36), BioBlitz (37), and eBird (38). Some even include an aspect of CEL, such as analyzing the microbiome of local feral cat populations (39) or testing local water sources for contamination. Our CEL-CURE is novel in that the research question that students ask each semester is dependent on the needs of our community partners, with topics ranging from public health questions of disease prevalence to intervention-based assessments of health. Students collaborate across disciplines and apply different research methods from public health, biology, and social work. These activities are grounded in the Interdisciplinary Science Framework proposed by Tripp and Shortlidge to guide students to tap into the interdisciplinary nature of science (40). We predicted students would make gains, not only in scientific content, but also cultural competency, communication skills, and perceptions of research. Our results provide evidence that the addition of CEL to a CURE course model can create an inclusive environment that positively impacts students' perceptions of science, value and respect for diverse individuals, and potentially lead to greater recruitment and retention of underrepresented populations in STEM.

METHODS

Ethics

This research was determined exempt by the Institutional Review Board at North Carolina Agricultural and Technical State University (IRB #19-0090). Because this was a retrospective study using only deidentified, course-generated materials, individual consent was not collected. The self-report surveys described below were optional for students, allowing for a nominal amount of bonus points (1% of final grade), and were used by instructors to assess course efficacy.

Participants

Study participants were comprised of students in three semesters of the course over 3 years: fall 2016 (initial pilot, *n* = 32), fall 2017 (*n* = 23), and fall 2018 (*n* = 25). Students came from a southeastern, large, historically black university (HBCU) and a small, private, liberal arts, predominantly white college (PWI), leading to diverse class demographics (Table 1). Although enrolled in the course at their own institution, students from both schools met together twice each week, alternating between institutions. Generally, students knew that this was a community-engaged, research-based, multi-institutional course prior to enrollment.

Course design

This team-taught course was designed to incorporate the hallmarks of CUREs: scientific practices, collaboration, iteration, authentic discovery, and broader relevance (5). Because the research projects were CBPR projects, we incorporated a second high-impact practice of CEL to build bridges and trust with the community. For details on course activities, see Appendix 2. Iteration, where students have opportunities to reflect and revise, was a key component of the course (Appendix 2, Table 1).

Inclusion and diversity

The HBCU contained large proportions of historically underrepresented individuals in STEM (85% African American, 25% first generation, 85% low Socioeconomic status). Therefore, we structured activities aimed at inclusion, including extensive small group work, community engagement hours, and metacognitive reflections focused on improving collaboration skills and the role of community engagement in bridging relationships between academia and the community. Approaching the class as a community of practice fostered a sense of shared learning amongst our students and gave voice to multiple perspectives. These activities have been demonstrated to foster and support diversity of all learners (ability, race, social class, ethnicity, religion, and gender) (25, 29, 30, 41). Additionally, research projects were intertwined with community engagement, targeting the communal goals frequently held by URMs (42, 43). Pedagogically, we invited students to bring their culture into the classroom and discussed deeper layers of culturally responsive pedagogy than those most common demographic identifiers. For example, at the HBCU, students call faculty Dr. X or Professor X; at the PWI, faculty are addressed by their first names. We discussed the rationale for why titles are important at an institution where historically underrepresented individuals had to fight against racism to earn those titles. On a deeper level, during a discussion about disciplining children at a community engagement activity, we had an intense class discussion about why alternate styles of discipline and values of learning may be different across varied communities.

TABLE 1.
Demographic information for students enrolled in the course.

Demographic Category	No. (%)
Total no. of students (3 semesters)	80
Institution	
HBCU	46 (57.5%)
PWI	34 (42.5%)
Gender	
Female	60 (75%)
Male	20 (25%)
Age ± SD	20.9 ± 2.8
Ethnicity/Race	
Black	43 (53.8%)
White	17 (21.3%)
Hispanic	8 (10.0%)
Asian	6 (7.5%)
Multiracial	3 (3.8%)
Nonresident aliens	3 (3.8%)
Status	
Freshman	6 (7.5%)
Sophomore	35 (43.8%)
Junior	22 (27.5%)
Senior	16 (20.0%)
Post-Baccalaureate	1 (1.3%)
Major[a]	
Biology	71 (88.8%)
Health Sciences	8 (10.0%)
Social Work	4 (5.0%)
Psychology	2 (2.5%)
Chemistry	2 (2.5%)
Environmental Studies	2 (2.5%)
Food & Nutritional Sciences	1 (1.3%)
Geology	1 (1.3%)
Religious Studies	1 (1.3%)
Undeclared	1 (1.3%)
German	1 (1.3%)
Sustainable Food Systems	1 (1.3%)
Computer Tech Info Systems	1 (1.3%)

[a] For majors, percentages may add up to more than 100% because of students pursuing double majors.

Research projects

Our students engaged in one of three different research projects, all centered around health disparities in underserved communities in our home city. Project 1 entailed a collaboration with coauthors Drs. Morrison and Sudha and the Montagnard Dega Association, Inc., and assessed potential anthropometric, behavioral, and psychosocial factors contributing to the incidence of hypertension in the this local Montagnard immigrant and refugee community. Project 2, a collaboration with Drs. Byrd and Byfield at the Center for Outreach in Alzheimer's Aging and Community Health, assessed the impact of book clubs on Alzheimer's health literacy. Project 3 was a collaboration with coauthor Dr. Nsonwu and the Congolese Women's Group and focused on the relationship between health concerns and English language skills within the Congolese refugee community. In each of these projects, students were trained for relevant research methods (data collection, quantitative and/or qualitative analyses), and each student developed a unique research question based on the data available.

Community engagement

Students chose from a range of community engagement experiences such as tutoring K–5 students, helping elderly individuals learn to read, and assisting with immigrant citizenship classes. Initially, a specific number of CEL hours were not required; however, in the second and third iteration of the course, a minimum of 10 and 15 hours of CEL were required, respectively.

Assessments

The pre- and post-exams were used as direct assessments of students' successful application of scientific process skills. They consisted of open-ended and multiple-choice questions regarding scientific method, graphing, data analysis, and statistics. Instructors scored pre- and post-exams together at the end of each semester. One instructor rescored all exams a second time when analyzing data for this research study, to ensure consistency across semesters. The remaining assessments were based upon published work; modifications to these surveys are included in Appendix 3. The Student Assessment of Learning Gains (SALG) instrument, consisting of Likert-style and open-ended questions, was used as an indirect measure of students' perceptions of learning gains in relation to changes in knowledge, skills, attitudes, pedagogy and effectiveness of classroom activities and resources (44). We added additional questions (Likert and open-ended) that reflected unique learning gains and evidence of an inclusive environment that we hoped to observe in this course (Appendix 3). The Networking (45) and Project Ownership Surveys (46), consisting of validated, reliable Likert-style questions, were used to differentiate between our course and published data on CUREs versus traditional cookbook laboratory courses. The Networking survey identifies to whom students discuss their research project and assesses whether students develop larger networks in CUREs than traditional laboratory courses. The Project Ownership survey measures students' emotions and attitudes toward their research project in addition to their perceptions of autonomy and ownership towards their research. We did not perform our own validity and reliability measures for these data; thus, our findings should be considered preliminary.

Qualitative analysis

A code book was developed based on (i) a review of the literature on CUREs and (ii) empirical coding of open-ended questions on the SALG survey, using thematic analysis amongst three individuals (47). Codes were revised through several iterations until consensus was achieved (Appendix 4). Dedoose was used for coding and inter-rater reliability tests. Initially, all excerpts were coded by two individuals with discussion to resolve coding differences. Once an inter-rater reliability score of 0.81 for the pooled Cohen's kappa was reached, one individual coded the remaining transcripts, with ample discussion between researchers.

Statistical analysis

IBM SPSS version 25 software was used to perform statistical analysis, including paired *t* tests and analyses of variance. Likert-style questions on the survey were converted into numerical values for analysis (48). To estimate effect sizes, Cohen's *d* was calculated (mean 1 – mean 2) / standard deviation. Sample sizes were too small to perform factor analysis.

RESULTS

Scientific process skills

We assessed student gains in scientific process skills both directly and indirectly. The instructors developed an assessment containing a mixture of data calculations, graph creation, multiple choice, short answer, and essay questions and administered it during the first and final weeks of the semester. Students entered the course with the strongest skills in the scientific method (identifying a research question, hypothesis, types of variables) and reading comprehension (pulling information from an abstract). Students exhibited weaker skills in statistics and laboratory math, and the weakest skills were in data analysis (Fig. 1A). The mean pretest scores ranged from 35% to 60% in categories of reading comprehension, math and statistics, and data analysis. On the final exam, students demonstrated significant gains in all areas that ranged from 65% to 86% ($p < 0.0001$, paired *t* test for all categories and total). Effect

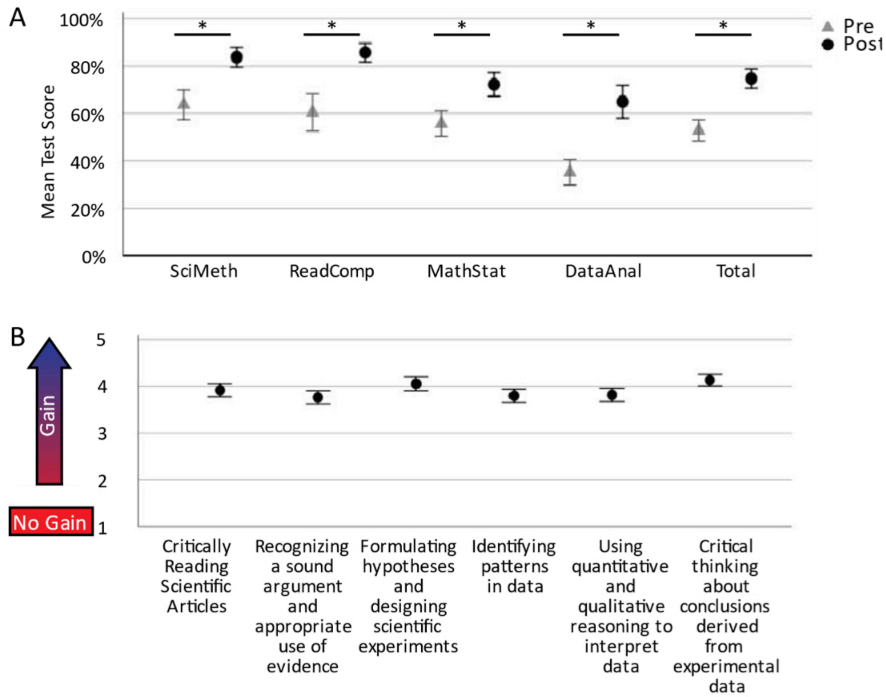

FIGURE 1. Scientific process skills. A) Pre- and post-scores for the four sections of the exam. n = 45 students who completed both pre- and post-exams. The mean, standard error, and effect size (Cohen's d) for each section and total score are as follows: scientific method (SciMeth; Pre 63.67% ± 3.09%; Post 84.10% ± 2.08%; d = 0.98); reading comprehension (ReadComp; Pre 60.40% ± 3.89%; Post 86.00% ± 1.95%; d=0.98), math and statistics (MathStats; Pre 55.73% ± 2.63%; Post 72.12% ± 2.44%; d = 0.92), data analysis (Pre 35.21% ± 2.69%; Post 65.38% ± 3.39%; d = 1.67); total (Pre 52.88% ± 2.25%; Post 74.89% ± 2.00%; d = 1.46) (*, $p < 0.0001$, paired t test). B) SALG Likert scores for student perceptions of learning gains. Students responded to the question that began, "As a result of your work in this class, what GAINS DID YOU MAKE in the following SKILLS?" Responses were selected from no gain (1), a little gain (2), some gain (3), good gain (4), or great gain (5). Likert responses were converted to numbers, and the means and standard errors were calculated: critically reading scientific articles, n = 59, 3.92 ± 0.137; recognizing a sound argument and appropriate use of evidence, n = 59, 3.76 ±0.140; formulating hypotheses and designing scientific experiments, n = 38, 4.05 ± 0.151; identifying patterns in data, n = 59, 3.80 ± 0.141; using quantitative and qualitative reasoning to interpret data, n = 38, 3.82 ± 0.140; select, compute, and interpret appropriate statistical analyses for analyzing biological data, n = 39, 3.92 ± 0.149; critical thinking about conclusions derived from experimental data, n = 38, 4.13 ± 0.126.

sizes were very strong, ranging from 0.92 to 1.67. We also calculated normalized gain to account for differences in pre-test scores. Normalized gains ranged from 39% in MathStats to 62% in Reading Comprehension (Appendix 5). These results were consistent with students' perceptions of their own gains on the Likert-style questions of the SALG survey. Students reported good gains in critically reading scientific articles, recognizing sound arguments based on evidence, and performing experimental design and analysis (Fig. 1B). These results provide evidence that students made gains in scientific process skills that would be expected for any successful laboratory course.

Inclusive teaching: collaboration and communication

Inclusive teaching practices involve creating opportunities for all individuals to feel valued. Hence, our classroom instructional approach included numerous opportunities to practice working in small groups, emphasizing the importance of equitable participation and active reflection on the efficacy of their teamwork. In the SALG survey, students responded that group activities were helpful to their learning, including in-class work (mean, 3.60 ± 0.168 on a point scale from 1 to 5), journal club presentations (3.7 ± 0.156), and poster presentations (3.79 ± 0.214) (Fig. 2A). Furthermore, the students developed skills in responding to constructive criticism, recognizing the value of listening to both their own and other groups' journal club critiques where the instructors and peers provided extensive detailed feedback on a slide-by-slide basis (3.81 ± 0.155, 3.81 ± 0.161, respectively). Not only did students find these activities helpful, but also they recognized learning gains in working with others, communicating effectively, and the value of collaborating across disciplines and institutions (Fig. 2B). Importantly, they denoted their strongest gains in being able to communicate with individuals different from themselves. Part of the intent of working interinstitutionally and interdisciplinarily was to encourage students to build a broader scientific network and social capital in their relationships. Students reported discussing the coursework with indi-

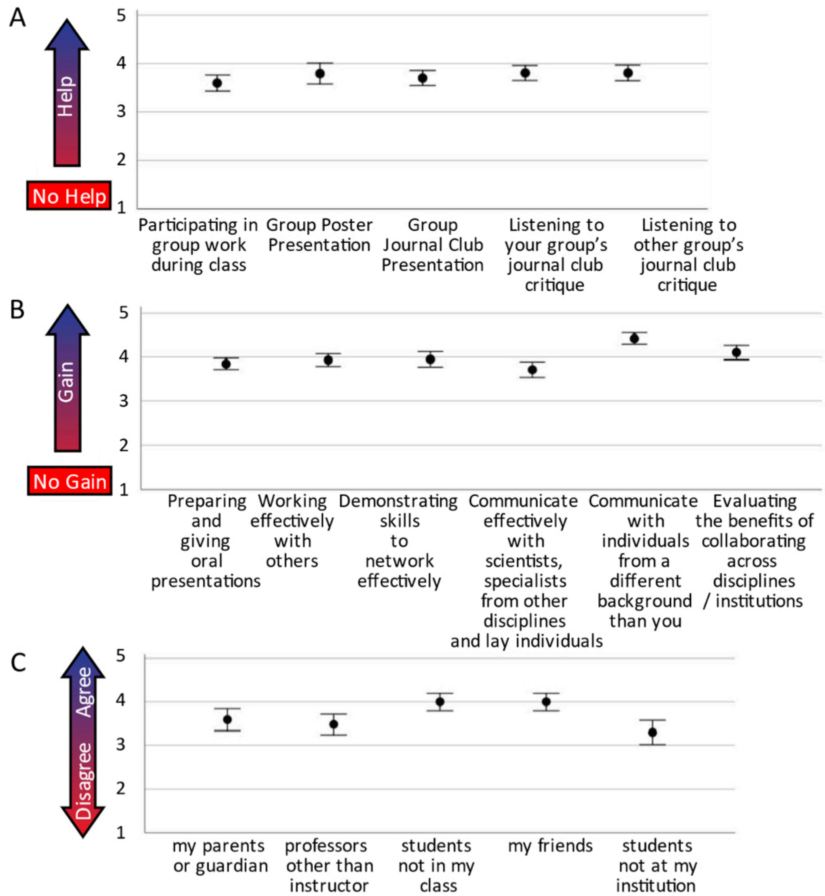

FIGURE 2. Inclusion and collaboration. A) Inclusive group activities. Students answered Likert-style questions that began, "HOW MUCH did the following aspects of the class HELP YOUR LEARNING?" Responses were selected from: no help (1), a little help (2), moderate help (3), much help (4), or great help (5). Likert responses were converted to numbers, and the means and standard errors were calculated (n = 57 students, except for group poster presentation, with n = 34, since this was added after the first semester): participating in group work during class (3.60 ± 0.168); group poster presentation (3.79 ± 0.214); group journal club presentation (3.70 ± 0.156); listening to your group's journal club presentation critiques (3.81 ± 0.155); listening to other groups' journal club presentation critiques (3.81 ± 0.161). B) Collaborative group activities. Students responded to the question that began, "As a result of your work in this class, what GAINS DID YOU MAKE in the following SKILLS?" Responses were selected from no gain (1), a little gain (2), some gain (3), good gain (4), or great gain (5). Likert responses were converted to numbers, and the means and standard errors were calculated: preparing and giving oral presentations (n = 38, 3.84 ± 0.130); working effectively with others (n = 58, 3.93 ± 0.143); demonstrating skills to network effectively (n = 39, 3.95 ± 0.176), communicate effectively with scientists, specialists from other disciplines, and lay individuals (n = 38, 3.71 ± 0.181); communicate with individuals from a different background than you (n = 38, 4.42 ± 0.129); evaluating the benefits of collaborating across disciplines and institutions (n = 39, 4.10 ± 0.163). C) Networking. Students answered the Likert-style questions that began, "I have discussed my research in this course with…" Responses were selected from strongly agree (5), agree (4), neither agree nor disagree (3), disagree (2), or strongly disagree (1). Likert responses were converted to numbers, and the means and standard errors were calculated (n=27 students): parents (or guardian; 3.59 ± 0.26); professors other than instructor (3.48 ± 0.24); students not in my class but at my institution (4.00 ± 0.22); my friends (4.00 ± 0.22); students who are not at my institution (3.33 ± 0.28).

viduals representing part of their personal social network (parents or guardians, friends) as well as scientific network (other professors) (Fig. 2C).

The SALG survey contained a number of open-ended questions that were thematically coded. The resulting data showed that students overwhelmingly mentioned communication, with 87.9% of respondents mentioning communication at least once (Table 2). This parent code of communication also contained sublevels of codes, with students mentioning communicating within their class group (53.4%), with faculty (20.7%), and with the community (27.6%). Consistent with students making good gains in recognizing the value of collaborating across institutions, 20.7% of students mentioned interinstitutional collaboration, despite the fact that this was never directly referred to in the open-ended questions.

While striving to create an inclusive classroom, we were also interested in fostering development of inclusive characteristics within our students. When asked to reflect on their own sense of inclusive values, students reported good

TABLE 2.
Gain in Communication Skills According to Student Responses to Open-Ended Questions in the SALG Survey.[a]

Parent Code	First-Level Subcode	Code Occurrence	Sample Excerpt
Communication		87.9%	"I participated all the time and I always asked questions. There were always different opinions in class and I always wanted to get my point across and to understand other peoples ways of thinking." (P42, Q21) "I am not a person who talks much, or communicates with others much. This project has helped me to open up and talk more with people I am not used to. In the beginning I was not able to understand why we had so many group projects, but I learned that this was a way to help us." (P4, Q76)
	With faculty	20.7%	"Both my instructors were a great help. I was able to communicate with my instructors, and any problems I had were handled. I was able to talk with them about anything, and freely add my ideas to the class." (P4, Q24)
	With peer leaders	1.7%	"I don't remember many opportunities to work with the student leaders outside of class, but it was good to be able to discuss the statistics with [the peer leader] in class that one time" (P25, Q34)
	With community	27.6%	"Finding alternate ways to communicate with individuals who speak a different language. Being patient, helpful, consistent, and caring with non English speaking individuals." (P30, Q10) "(I learned) How to work with immigrants and communicate through different language barriers. Establish trust, and apply knowledge to the situation" (P20, Q10)
	Within class group	53.4%	"Interacting with peers during class significantly helped my understanding of class topics." (P38, Q34)
	Networking	20.7%	"I have gained better community engagement skills, such as my approach to certain communities that I might not be familiar with. And also better networking and group skills because this class was filled with many different group collaborations." (P2, Q10)
Interinstitutional Collaboration		20.7% (12/58)	"I think that this class really helped me see the importance of working with others especially with people [from] a different institution. Even though it was the worst part of the class for me I thought the group work in the class helped me understand the importance of good communication and the importance of delegating work within a group." (P1, Q10) "The joint nature of this class was my favorite part, since I was able to meet and work with people from another college. [These schools] are pretty far apart [7 miles], and I probably wouldn't have met anyone otherwise, so it was a good chance to see things from another perspective by learning together." (P25, Q48)

[a] Responses were independently coded by two researchers, with an interrater reliability of 0.81 for Cohen's kappa. Percentages represent numbers of participants for which the relevant code was applied at least one time. Note that for interinstitutional collaboration, no open-ended questions specifically asked about the interinstitutional nature of the course. The term Parent code refers to a broad term that summarizes several more specific terms, i.e., the subcodes.

to great gains in their attitudes surrounding the impact of oppression and privilege (4.14 ± 0.153 on a five-point Likert scale) and respect for cultural differences (4.36 ± 0.147). Importantly, they recognized that development of cultural competency is a continuum rather than an endpoint. Thus, they also made good to great gains in their continued interest in maturing cultural awareness within oneself (4.24 ± 0.146).

Our holistic approach to assessment enabled us to obtain evidence for how this inclusiveness developed. When asked an open-ended question, "What was your favorite part of this Biology class?", over half of the students responded that the community engagement was their favorite (54.3%) (Table 3). Similarly, aspects of communication were mentioned frequently (51.4%), including informal communication (34.3%), networking (17.1%), or talking with the community (14.3%), as well as formal scientific presentations (17.1%) and journal club presentations (11.4%). Additionally, aspects of their collaborative group work were mentioned by more than 10% of the students (11.4%). These responses suggest that the students valued their time working with the community as well as working with others, reflecting the importance of communal goals.

Broader impacts of science and society

One major purpose of engaging students in both CEL and CUREs was to help students recognize the communal nature of research. Evidence that this goal was at least partially met is reflected in students' gains being good to great in distinguishing the differences between CBPR and traditional laboratory research (4.59 ± 0.115) (Fig. 4) and explaining the challenges that societal concerns present to science (4.23 ± 0.130). Moreover, students recognized that CBPR can make an impact on communities (4.51 ± 0.127) and help address real-world issues (4.13 ± 0.118). Comparing responses from our students to published data regarding CURE and non-CURE laboratories from the Project Ownership and LCAS surveys demonstrated our students' recognition of the discovery and broader impacts of our course, providing evidence that the structure of this course reflects a CURE (46, 49) (Appendices 6 and 7). When answering an open-ended question about how their understanding of CBPR has changed, students articulated the collaborative and impactful nature of this type of research, despite the challenges of human subjects research (Table 4).

Inclusive teaching and persistence

While developing future research interests is not necessarily the end goal of inclusive teaching, it is an important outcome for increasing the number of URM students in STEM. When asked Likert-style questions about their future interests, more than three-quarters of the students made gains in their interest in future undergraduate research, with almost 50% reporting a good to great gain (79%) (Fig. 5A). Fewer students reported gains in pursuing a research career; however, 63% still reported at least a little gain and 26% a good to great gain (Fig. 5B). In contrast, students made greater gains in their interest in community activism and in working with diverse individuals (Fig. 5C). We cannot distinguish whether this interest in research simply occurs because the course is a CURE or because it is a CEL-CURE.

DISCUSSION

Institutional and community changes

Puritty et al. (21) identified three major principles for institutions valuing diversity in STEM and striving for inclusion: (i) creating an institutional culture of equity and justice, (ii) fostering respect and valuing diverse backgrounds, and (iii) promoting opportunities for students to address societal concerns and engage with communities. In our study, we demonstrated successful implementation of a CEL-CURE, in which inclusion and diversity served as the foundation.

TABLE 3.
Favorite Parts of Class.[a]

Parent Code and Subcodes	Code Occurrence
Community engagement	54.3%
Communication	51.4%
Informal communication	34.3%
Networking	17.1%
Talking with community	14.3%
Scientific presentations	17.1%
Journal club presentations	11.4%
Collaboration or group work	11.4%

[a]Students were asked "What was your favorite part of this Biology class?" The responses to the question were coded by the team using a list of codes created based on themes found in the responses. The table reflects the percentages of individual excerpts to which the different codes were applied in response to this question. The term Parent code refers to a broad term that summarizes several more specific terms, i.e., the first-level subcodes and the even more specific second-level subcodes.

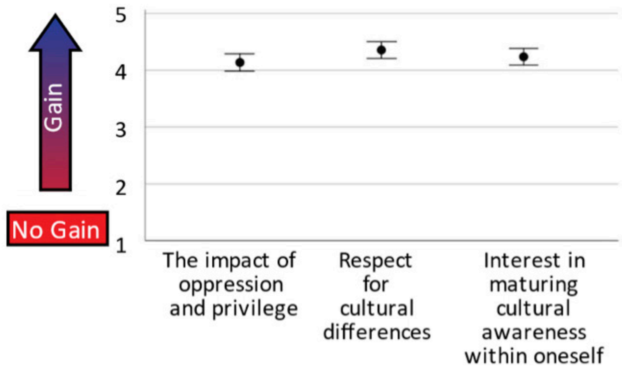

FIGURE 3. Cultural humility. Students answered the Likert-style questions that began, "As a result of your work in this class, what GAINS DID YOU MAKE in the following?" Responses were selected from no gain (1), a little gain (2), some gain (3), good gain (4), or great gain (5). Likert responses were converted to numbers, and the means and standard errors were calculated: impact of oppression and privilege (n = 58, 4.14 ± 0.153); respect for cultural differences (n = 50, 4.36 ± 0.147); interest in maturing cultural awareness within oneself (n = 50, 4.24 ± 0.146).

Our CEL-CURE is novel in that research projects vary based on the needs of our community partners, with topics ranging from public health questions of disease prevalence to intervention-based assessments of health. Some might argue that this type of research might be better suited to a public health program. Indeed, one outcome of this course was the development of a new public health major at the PWI, which is evidence that this type of community-based research course is valued by the institution. At the HBCU, public health is not represented as a major; thus, the students were exposed to unique opportunities. This course has also contributed to the long-standing relationships of our institutions with multiple community partners in a sustainable way, including support for the development of a community advisory council by the Montagnard immigrant and refugee community (https://www.montagnardda.org/research). Furthermore, our coauthors L. Siu, V. Ksor, and H. Mlo (i) are members of the Montagnard community, (ii) were also students at the PWI, (iii) served as cultural brokers with our students in the course, and (iv) were among the co-authors of the original manuscript documenting the development of the collaboration with this community (50). In addition, community members from the UMOJA Congolese women's group co-led a leadership workshop along with faculty and students from this course. These are examples of the community empowerment that have developed from our course, supporting evidence that this course represents a model through which significant gains in equity can be achieved.

TABLE 4.
Changes in Students' Understanding of CBPR.

"I now understand just how many different people are involved in this kind of research. It really is extremely integrative." (P53)
"I have learned what it takes to do a community-based participatory research and it is not easy, but definitely worthwhile." (P40)
"I feel like I understand the principles behind community-based research more than I did before. I feel like it is a better option for a lot of communities especially communities facing disparities since it gives them more control and authority when it comes to the extent of the research." (P1)

Diversity and inclusion: respect and value for diverse backgrounds

CUREs are designed to increase the capacity for, and equity of, undergraduate research opportunities. One reason for forming a hybrid CEL-CURE course between a HBCU and PWI institution was to introduce a level of diversity within the classroom not found at either institution alone. While other demographics (gender, age, and socioeconomic status) contribute to diversity, ethnicity is reported to be most important in the impact on academic research, albeit as measured by only one standard of success, the number of publication citations (51). Indeed, without specific prompts, students often mentioned the value of working with peers from other institutions. One might make a stereotypical prediction that PWI students made greater gains in cultural competency that HBCU students. We did not disaggregate these findings due to the small sample size and privacy concerns. However, numerous situations suggest that this is not the case. As an example, our class did the "Privilege Walk" as part of a cultural competency exercise (52). Here, everyone starts in a straight line but then takes steps forward or backward in response to prompts, such as, "Take a step forward if you routinely read about people of your ethnicity in history class." Or, "Take a step back, if you have ever been followed by an employee around a store." During this scenario, three of our Montagnard immigrant co-authors ended up in vastly different positions in the walk, with one co-author ending up near the back of the group, another ending up near the very front, and the third ending up in the middle. Despite having grown up in the same neighborhood after immigrating to the United States, with the same ethnicity, and attending the same college, they had different experiences and different perceptions of their experiences. During the same activity, one African American student who finished the exercise near the front mentioned that she actually thought racism didn't exist anymore because she hadn't experienced it in her multicultural community growing up… until she listened to her classmates discuss their experiences during the debrief. We encourage readers not to make assumptions about who will benefit more from discussions of cultural sensitivity; in our experience, virtually all of our students make significant gains, just for different reasons. One reason may be that we are focusing on all students making gains for the shared vision of

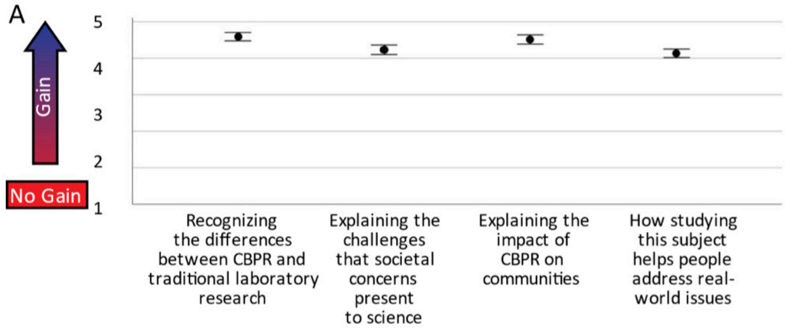

FIGURE 4. Broader impact of science. Students answered Liker-style questions that began, "As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of the following?" Responses were selected from no gain (1), a little gain (2), some gain (3), good gain (4), or great gain (5). Likert responses were converted to numbers, and the means and standard errors were calculated: recognizing the differences between CBPR and traditional laboratory research (*n* = 39, 4.59 ± 0.115); explaining the challenges that societal concerns present to science (*n* = 39, 4.23 ± 0.130); explaining the impact of CBPR on communities (*n* = 39, 4.51 ± 0.127); how studying this subject area helps people address realworld issues (*n* = 60, 4.13 ± 0.118).

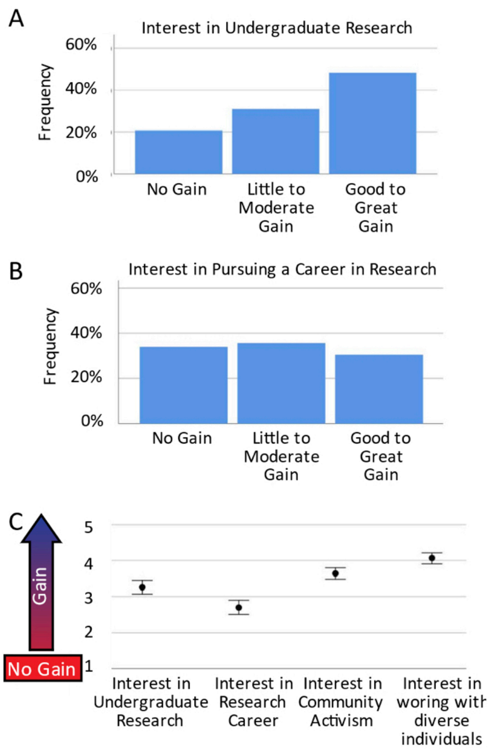

FIGURE 5. Future interests. Students answered Likert-style questions that began, "As a result of your work in this class, what GAINS DID YOU MAKE in the following?" Responses were selected from no gain (1), little gain (2), moderate gain (3), good gain (4), or great gain (5). A) Interest in undergraduate research. Response frequencies (percentages) are shown for no gain (20.7%), a little to moderate gain (31.0%), and good to great gain (48.3%) (*n* = 58). B) Interest in pursuing a career in research. Rather than calculating a combined mean score, response frequencies (percentages) are shown for no gain (33.9%), a little to moderate gain (35.6%), and good to great gain (30.5%) (*n* = 58). C) Likert responses were converted to numbers, and the means and standard errors were calculated. Interest in undergraduate research (*n* = 58, 3.26 ± 0.19); interest in pursuing a career in research (*n* = 59, 2.69 ± 0.20); interest in community activism/advocacy (n = 59, 3.64 ± 0.16); interest in working with individuals from different ethnicities, backgrounds, socioeconomic status, or geographical location (*n* = 59, 4.07 ± 0.15).

being effective community partners rather than focusing on one set of students being responsible for educating another set of students.

Interestingly, the demographics of the course participants did not always match the demographics of the institution. With regard to the PWI, we often observed a higher enrollment in the percentage of URMs in the course than is representative of the institution. This could be because, as a group, URMs are more likely to hold communal goals of helping others and thus might be attracted to a course like this (53–55). Generally, students were aware of the course structure prior to adding it to their schedule; hence, our findings are subject to selection bias in the types of students who are likely to register for this course. The importance of building lasting relationships with the community deems it unethical to enroll students who have no desire to engage with the community and may be noncompliant. For this reason, scaling this type of course to all students in the major or even nonmajors may not be desirable or feasible. However, there are many programs that focus on a small cohort of students to support their success; those students can change the culture of their department by serving as role models for others who were not part of the program (56, 57).

Impact on perspective and behavior

By the end of our course, students valued diverse perspectives, not just from each other but also from the communities with whom we work, which often consist of individuals of lower socioeconomic status and lower educational attainment but who have rich cultural and social capital. Initially, students had ideas about "fixing" the community, stemming from a paternalistic, top-down approach. However, inclusion requires valuing community member opinions and their lived experiences. We worked hard throughout the semester to value community members as equitable partners. Students' favorite aspects of the course focused on working with the community. Several students have continued volunteering with the community beyond the end of the course, and this is evidence of enjoyment, value, and long-term behavioral changes.

It is one thing to bring diverse students together to work on collaborative projects, but does this diversity cross outside of those boundaries? Measuring this concept is difficult, though it has been accomplished by analyzing social networks (58). Anecdotally, we have observed several cross-institutional friendships develop where students attended extracurricular activities at the other institution. Although we have not collected structured longitudinal data, we do see our students engaging in faculty-mentored undergraduate research experiences, applying to and completing summer research programs, and entering graduate and medical schools after completing this course, often mentioning this course as a significant event in their education. Due to the collaborative aspect of the research projects, our students are expanding their scientific networks even beyond our two institutions. Based on our findings, this hybrid CEL-CURE course effectively provides students with a range of skills not only common to other CUREs reported in the literature (5, 49, 59, 60) but also significant soft skills of culturally competency, a valuable rarity for a scientific course. This course serves as a model for creating a diverse, inclusive environment for engaging students in research that impacts and engages them in their local community.

SUPPLEMENTAL MATERIALS

Appendix 1: Constructivist learning theory
Appendix 2: Course design, iteration opportunities, and syllabus
Appendix 3: Assessments of student learning
Appendix 4: Code list (Table S2)
Appendix 5: Normalized gains in scientific process skills (Fig. S1)
Appendix 6: Project ownership survey (Table S3)
Appendix 7: LCAS survey (Table S4)

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