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Student Perceptions of Undergraduate Research-Infused Courses

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Abstract

Colleges and universities nationwide have attempted to address the persistent demographic disparities in the health-related research workforce – particularly the lack of Black/African-American and Hispanic/Latinx researchers – by engaging traditionally underrepresented minority students in research early in their undergraduate academic careers. Previous efforts have focused on formal research training programs or course-based undergraduate research training, which commonly serve small student populations and are narrow in scope. With support from the NIH Building Infrastructure Leading to Diversity (BUILD) grant, California State University, Long Beach (CSULB) developed research-infused courses that introduce students to methods and skills for biomedical and behavioral research as well as enhance students' understanding of health disparities and the value of interdisciplinary approaches to solving problems. This study aims to identify promising pedagogical strategies and understand the extent to which students' ethnic minority status and formalized research training experience are associated with their perceptions of personal development gains and research and technical skills. Based on student survey data (N = 410) across three academic years, findings from this study indicate that research-infused courses have the potential to equitably engage students, regardless of their race/ethnicity and participation in formal research training. In addition, research-infused courses could potentially serve as a mechanism for colleges and universities to institutionalize opportunities for a broad range of students to be exposed to research methods and skills-building.

Introduction

The health-related research workforce – consisting of biomedical and behavioral sciences and engineering – does not currently reflect the diversity of the United States population. According to the National Science Foundation (National Science Foundation, 2019), White and Asian graduates make up a disproportionately large share of science and engineering highest degree holders (66.4% and 15.7%, respectively) compared with the general U.S. adult population (64.1% White and 5.8% Asian). Underrepresented ethnic minority (URM) investigators, defined by the National Institutes of Health (NIH) as individuals identifying as Black/African-American, Hispanic/Latinx, American Indian or Alaska Native and/or Native Hawaiian or Other Pacific Islander, continue to lack a presence in these advanced areas of the science and engineering workforce.

Moreover, the U.S. educational system is not producing a diverse pool of graduates in health-related disciplines, which continues to perpetuate the demographic disparity in the health-related research workforce. In the most recent data from the Survey of Earned Doctorates, among the 20,153 U.S. citizen and permanent resident doctorate recipients in health-related disciplines in 2019, 5.9% of recipients were Black/African-American, and 8.4% were Hispanic/Latinx, while 79.2% were White or Asian (National Science Foundation, 2020). While the proportion of Black/African-American and Hispanic/Latinx doctorate recipients has increased from a decade earlier (from 5.3 to 5.9% and 5.6% to 8.4%, respectively), minorities are still vastly underrepresented in advanced health sciences (National Science Foundation, 2010, 2020). According to recent estimates in 2019, Black/African-Americans make up 13.4% of the U.S. population, and Hispanic/Latinx individuals make up 18.5% of the general population (U.S. Census Bureau, n.d.). This lack of diversity in the scientific community omits important and unique perspectives that could foster innovative solutions to scientific questions.

Review of Relevant Scholarship

Approaches to Addressing Inequities. One approach to addressing this inequity is engaging URM students in research and science early in their college careers. Prior studies have established the importance of undergraduate research and mentoring interventions on student retention, achievement, and science identity (Griffin et al., 2010; Hurtado et al., 2011). Engaging students early and successfully retaining them in science and research has been attempted in a number of ways. Two broad methods that have been used to engage undergraduate students and build interest in a research career are formal research training programs, such as those funded by NIH, and course-based undergraduate research experiences (CUREs).

Formal Research Training Programs. Studies demonstrate that formal research training programs, or undergraduate research experiences (UREs), can promote positive outcomes for higher education students in STEM, particularly URM students. Participating in research training provides students with support and experiences that lead to gains in personal, professional, scientific, and technical skills (Lopatto, 2007). Participants who complete a research training experience are also significantly more likely to enroll in a STEM graduate program (Eagan Jr et al., 2013; Lopatto, 2007).

In a study involving 6,834 students from the University of California, Davis, Jones et al. (2010) found that UREs improved outcomes for URM students in biology along with measures of persistence, graduation, and performance (graduating with at least a 3.0). Their research demonstrated that gains for URM students were significantly greater than for non-URM students, suggesting that URMs have the most to gain from participating in early research experiences. Although studies of liberal arts and social sciences UREs are limited, some scholars have also documented how URE support students in these disciplines (Gray et al., 2015; Zimbardi & Myatt, 2014). While formal research training programs are effective at helping students – particularly URM students – remain in science and matriculate on to doctoral programs, one drawback to these types of training programs is that they can serve only a limited proportion of undergraduate students. These programs are often highly selective, and their reach is constrained by funding and faculty available to provide mentorship (Jones & Lerner, 2019).

Course-Based Undergraduate Research Experiences. The literature on the effectiveness of undergraduate research courses is more limited. The majority of studies of undergraduate research and mentoring interventions have focused on laboratory experiences (i.e., formal internships and other shorter hands-on projects) under the mentorship of a faculty member during a student's undergraduate career. For students who are new to research – or are not yet ready to commit to a formal training program or specific lab experience – these types of courses can provide exposure to research as a potential and attainable career pathway (Auchincloss et al., 2014).

Scholars have shown that teaching science and research at the undergraduate level has required reimagining pedagogical approaches, particularly for engaging traditionally underrepresented students (Eliason, 2019). CUREs offer opportunities for innovative engagement. What constitutes a CURE can vary, but some common elements include the use of scientific practices, discovery, broadly relevant or important work, collaboration, and iteration. All five must be integrated into one course, but the intensity and frequency of each component may vary (Auchincloss et al., 2014). In prior research by Jones and Lerner (2019), implementing CUREs increased the percentages of students who had meaningful research experiences by the time they graduated. Moreover, studies indicate that CUREs could help close opportunity gaps between URM students and non-URM students (Bangera & Brownell, 2014).

CUREs also address challenges with traditional UREs such as formal research training programs, including the lack of faculty mentors available for one-on-one mentoring, financial barriers (e.g., students giving up paid work opportunities for unpaid lab research assistantships), and limited funding for formal research training. In addition, research courses are more feasible than formal programs for institutions to implement. Modifying the curriculum to embed meaningful research-based student learning outcomes into courses is potentially cost-effective and could yield higher participation in research experiences. Bangera and Brownell (2014) argue that these courses can serve as the first gateway to research and ultimately change a student's entire career trajectory.

It is particularly important to engage URM students early in their undergraduate careers. Olivares-Donoso (Olivares-Donoso & González, 2019) stated that for the sciences specifically, it has been shown that linking research and teaching from the first year (and as early as possible) promotes better learning outcomes for STEM students than lab experiences, in many respects. In comparing lab experiences to courses, Olivares-Donoso found that research-based courses are better for "thinking and working like a scientist" along with all subcategories of "skills" except "laboratory skills." In contrast, undergraduate research is beneficial to students for growing in "developing an identity as a scientist" and "understanding of professional practice." Holmes and Wieman (2016) reported that cognitive tasks that engage students differ slightly between courses and lab work. Ultimately, courses and lab work complement each other (Olivares-Donoso & González, 2019).

While studies show positive outcomes resulting from undergraduate students participating in research programs and CUREs, gaps in the literature exist. First, CUREs vary considerably across colleges and universities, so it is crucial to understand and "identify the activities within CUREs likely to directly result in these short-term outcomes, delineating both rewards and difficulties students encounter" (Auchincloss et al., 2014). Second, much of the literature on CUREs addresses undergraduate research training courses, and much less is known about research-infused courses – courses that focus on research but do not meet the standard definition of a CURE and are designed for a broader student population. Third, more research is needed to understand what students specifically gain from CUREs and research-infused courses and which components are the most valuable. This present study contributes to this knowledge in the literature by addressing these three gaps.

Study Objectives and Research Questions

The benefit of a diverse research workforce has been established. However, recruitment and retention of underrepresented groups in the pipeline remain a challenge. Novel and sustainable practices to support underrepresented students' training and continued pursuit of research careers are needed. Thus, the impact of the research-infused courses developed by the California State University, Long Beach (CSULB) Building Infrastructure Leading to Diversity (BUILD) Program on students' perceptions of gains in personal development (referred to as *personal gains*) and gains in research and technical skills (referred to as *skills gains*) is investigated. Identifying promising approaches that can be institutionalized, such as research-infused courses, may broaden the availability of research exposure and skills training. Integrating research skills development into the curriculum opens the door for a larger proportion of URM students to engage in research and training, which could ultimately contribute to the diversification of the research workforce.

The two overarching objectives of this paper are (1) to evaluate student perceptions of undergraduate research-infused courses to identify promising strategies to integrate into future CUREs and other course-based research initiatives, and (2) to understand the extent to which students' ethnic minority status and formalized research training experience are associated with their perceptions of research-infused courses. The three research questions for this study are the following:

1. Which course components and perceived personal and skills gains of the undergraduate research-infused courses were rated highest by students?
2. Are there differences in students' perceptions of the undergraduate research-infused courses between underrepresented ethnic minority students and non-minority students?
3. Are there differences in the students' perceptions of the undergraduate research-infused courses between those who did and did not participate in a formal research training program?

Methods

Participants. The study sample consisted of all undergraduate CSULB students (*N* = 361) enrolled in four research-infused courses during three academic years: 2016-17, 2017-18, and 2018-19. The four courses were the following: Interdisciplinary Approaches to Health Disparities (IAHD), Introduction to Research Methods (IRM), Scientific Research Communication (SRC), and Advanced Research Methods (ARM). Of the 361 students, 49 enrolled in two or more courses. Including multiple enrollments, there were 410 survey responses across the entire time period of analysis.

Of the 361 students, 174 participated in BUILD and Research Initiative for Scientific Enhancement (RISE) undergraduate research training programs funded by NIH. Both programs included undergraduate students from health-related disciplines in the College of Engineering, College of Liberal Arts, College of Natural Sciences and Mathematics, while students from the College of Health and Human Services participated only in the BUILD program. BUILD and RISE students participated in a training curriculum that consisted of faculty-mentored research experience, Learning Community Seminars (both summer and academic year), and research-infused courses. The program activities were designed to support student development of basic and advanced research methods as well as professional development skills necessary to build their confidence as a researcher and successfully apply to doctoral programs. Program requirements for BUILD and RISE students – including recommended research-infused coursework – differed based on class standing at entry and whether students participated in the programs for one or two years. Two additional students participated in the NIH-funded Maximizing Access to Research Careers (MARC) program, and eight other students reported participating in other undergraduate research training programs.

Research-Infused Courses. The CSULB BUILD Program developed courses that introduce students to methods and skills for biomedical and behavioral research and enhance students' understanding of health disparities and the value of interdisciplinary approaches to solving problems. The courses were developed by a team of faculty from engineering, natural, behavioral, and social sciences disciplines and were distributed at different academic levels appropriate to students' academic preparation. This paper focuses on four research-infused courses taken by students in the research training programs as well as by students not enrolled in the programs, as the courses were open to any CSULB students. Three of these courses were approved as General Education (GE) courses. The GE certification was critical as it allowed students to fulfill their GE requirement(s) without adding additional coursework that could delay their graduation. The descriptions of the course content are provided below.

Interdisciplinary Approaches to Health Disparities (IAHD). This sophomore-level course explores biological, social, environmental, and systemic factors associated with the disproportionate prevalence of health issues and diseases among underserved populations. Using problem-based approaches, students learn about interdisciplinary research and interventions to affect positive health outcomes and access for underserved, underrepresented diverse populations in a culturally relevant way. This course was approved as a GE course under the Social Science and Citizenship requirement.

Introduction to Research Methods (IRM). This sophomore-level introduction to biomedical research methods course was designed to introduce topics such as principles of data collection and handling, responsible conduct of research, experimentation, hypotheses formulation, and testing, measurement, naturalistic observation, correlation studies, analysis, and reporting, common in biomedical sciences. The course engages students in critical thinking and using the scientific method to gain knowledge of factors that impact human life. The course gives students the initial skill set they need to start in directed research successfully.

Scientific Research Communication (SRC). A junior-level course that emphasizes communication of science to all, from the general public to disciplinary colleagues. Research tracking, reports, proposals, manuals, and journal articles were other primary topics. The main aim of the course was to build proficiency in oral and written communication and engage students in intensive practice in writing, editing, and evaluating scientific reports, with specific reference to discipline-specific methodologies as related to scientific inquiry and research. These are critical skills for research scientists and help prepare the student to enter graduate study. This course was approved as a GE Writing Intensive Capstone course.

Advanced Research Methods (ARM). This senior-level advanced biomedical research methods course engages students in hypothesis testing, experimental design, methodological and technical procedures for experimentation, identifying funding sources (NIH and other sources), and grant writing. The course provides an in-depth knowledge of scientific research, emphasizing the connection between research design and statistical analyses. The course covers literature review, hypothesis generation, types of research designs, and conceptual approaches to data analyses. Its priority is to provide students with a skill set that prepares them for graduate study and biomedical research careers. This course was approved as a GE Advanced Skills Capstone course.

Student Survey

The primary source of data for this study is student course evaluation surveys. The number of survey items varied by course and ranged from 50 to 70 questions, including demographics, personal and skills gains questions, and course-based questions, in addition to several open-ended questions. A number of introductory items gathered demographic data, including gender, race, ethnicity, academic college/department, and whether the student is part of a formal research training program. Using Likert-scale response types, the survey items then asked students to report on their experiences and how much they gained in terms of skills, confidence, and understanding as a result of the course. These survey items were adapted from the Undergraduate Research Student Self-Assessment (URSSA; Weston & Laursen, 2015). Specifically, course survey items came from two URSSA scales: "Gains in skills" and "Personal gains related to research work.", which were thematically organized for administration at CSULB into survey items on *personal gains* and *skills gains*. Survey items on personal gains were measured on a 4-point Likert-scale ranging from "strongly disagree" to "strongly agree." Sample items included, "This course has confirmed my interest in pursuing a research career," and "This course has prepared me for advance coursework or thesis work." Survey items on skills gains were measured on a 5-point Likert scale ranging from "no gains" to "great gains" with the question stem of "How much did you gain in the following area as a result of this course?" Students reported gains in various areas, from understanding journal articles, making oral presentations, and writing scientific reports to working collaboratively with others.

Following these research experiences items which were standard across courses and semesters, students responded to additional survey items that varied by course and term. These items asked students about the value of specific modes of instruction (lectures, group projects, films, et cetera); another set of items was related to specific topics covered in the course. The question stem for these course-specific survey items was, "How much did the following support your learning?" Students responded to these items on a 4-point Likert scale ranging from "not at all" to "a great deal."

Procedures. A hard copy survey was administered to students at the end of the semester, usually on the last day of class or during the week of final examinations. An external evaluator (from CSULB's Center for Evaluation and Educational Effectiveness) visited the classroom, introduced the evaluation, and distributed surveys. Students were asked to complete surveys independently and keep responses private.

Survey administration took approximately 15 minutes. Evaluators collected completed paper surveys, and CSULB graduate student assistants entered responses into Microsoft Excel. Variables were defined and labeled to ensure consistency across terms, and values were assigned to each response type. Multiple graduate student assistants were involved in survey transcription and double-checking of transcription entries to ensure the accuracy of the electronic survey data. Study procedures were approved by the CSULB Institutional Review Board.

Data Analysis. After the hard copy survey data were entered, checked, and cleaned in Microsoft Excel, the electronic survey data were then transferred to IBM SPSS Statistics for Windows, Version 26 (IBM Corp., Armonk, NY) for additional data cleaning and coding and subsequent analysis of descriptive and inferential statistics. For this study, survey results were analyzed by course, and survey responses for courses across terms were combined for analysis. For IAHD, five sections were combined, four sections were combined for IRM, six sections were combined for SRC, and three sections were combined for ARM.

Following the NIH definition, students who self-identified as Black/African-American, Hispanic/Latinx, American Indian or Alaska Native or Native Hawaiian or Other Pacific Islander were classified as URM students. All other students were classified as non-URM students. Independent samples *t*-tests were conducted separately by course to compare mean differences for each Likert-scale survey item on ratings of course components, skills gains, and personal gains based on URM status. Students who self-identified as participating in an on-campus formal research training program were compared against students who did not participate in any formal research training program. Independent samples *t*-tests were then conducted separately by course to compare mean differences for each Likert-scale survey item on ratings of course components, skills gains, and personal gains based on research training program status.

Across all survey items, students with missing data were omitted from analyses. In cases where the parametric statistical assumption of homogeneity of variance was not met, statistical results are reported with equal variances not assumed. In addition to highlighting statistically significant differences, effect sizes are also reported using Cohen's *d* and interpreted using suggested *d*-value cutoffs of 0.2 = small effect, 0.5 = medium effect, and 0.8 = large effect (Cohen, 1988). In some instances, some non-significant differences (likely due to some small sample sizes in some courses) still yielded moderate to large effects. Non-significant findings with *d*-values of at least 0.4 are reported to indicate areas that may be of additional interest and investigation. Because of the large number of independent samples, *t*-tests were conducted and results that did not produce medium/large effect sizes are not reported.

Results

The total unduplicated sample (N = 361) was 46.8% female, 44.3% male, and 8.9% unknown. URM students comprised 46.3% of the sample; by racial/ethnic category, 29.6% of students in the sample were Asian, 4.7% were Black/African American, 41.6% were Hispanic/Latinx, 14.1% were White, 3.3% were Multiracial, and 6.6% were of unknown race/ethnicity. Of the sample, 51.0% participated in a research training program. By discipline, 59.0% were in biomedical sciences and engineering majors, and the other 41.0% were in behavioral sciences majors. See Table 1 for demographic characteristics of the sample by course.

Table 1. Student Demographics by Course

Characteristic	IAHD		IRM		SRC		ARM	
	n	%	*n*	%	*n*	%	*n*	%
Gender								
Female	82	53.6%	28	45.2%	63	38.7%	19	59.4%
Male	68	44.4%	20	32.3%	73	44.8%	13	40.6%
Other/Unknown	3	2.0%	14	22.6%	27	16.6%	0	0.0%
Race/Ethnicity								
American Indian/Alaska Native	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Asian	42	27.5%	13	21.0%	52	31.9%	10	31.3%
Black/African American	10	6.5%	2	3.2%	8	4.9%	2	6.3%
Native Hawaiian/Pacific Islander	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Hispanic or Latinx	74	48.4%	25	40.3%	52	31.9%	17	53.1%
Two or More Races	4	2.6%	1	1.6%	9	5.5%	0	0.0%
Unknown	1	0.7%	9	14.5%	23	14.1%	0	0.0%
White	22	14.4%	12	19.4%	19	11.7%	3	9.4%
Research Program Participation								
Yes	85	55.6%	42	67.7%	64	39.3%	31	96.9%
No	68	44.4%	20	32.3%	99	60.7%	1	3.1%

Note. *N* = 410. IAHD = Interdisciplinary Approaches to Health Disparities; IRM = Introductory Research Methods; SRC = Scientific Research Communication; ARM = Advanced Research Methods. Headcount includes 49 students who enrolled in multiple courses. Percentages may not equal 100 due to rounding.

Interdisciplinary Approaches to Health Disparities. *Course Component Ratings.* Student ratings of the IAHD course components and topics are reported in Table 2. The final project was perceived to be the component most useful for supporting learning. Learning about the prevalence of health disparities across diverse groups was rated highest among topics that supported learning, whereas exams were rated lowest. There were no significant differences in course component ratings by URM status. Non-trainees (mean = 3.47, standard error = 0.10) gave higher ratings for IAHD lectures supporting their learning compared to research program trainees (mean = 2.99, standard error = 0.12), $t(150.3) = -3.05$, $p = .003$, $d = 0.49$ (small effect).

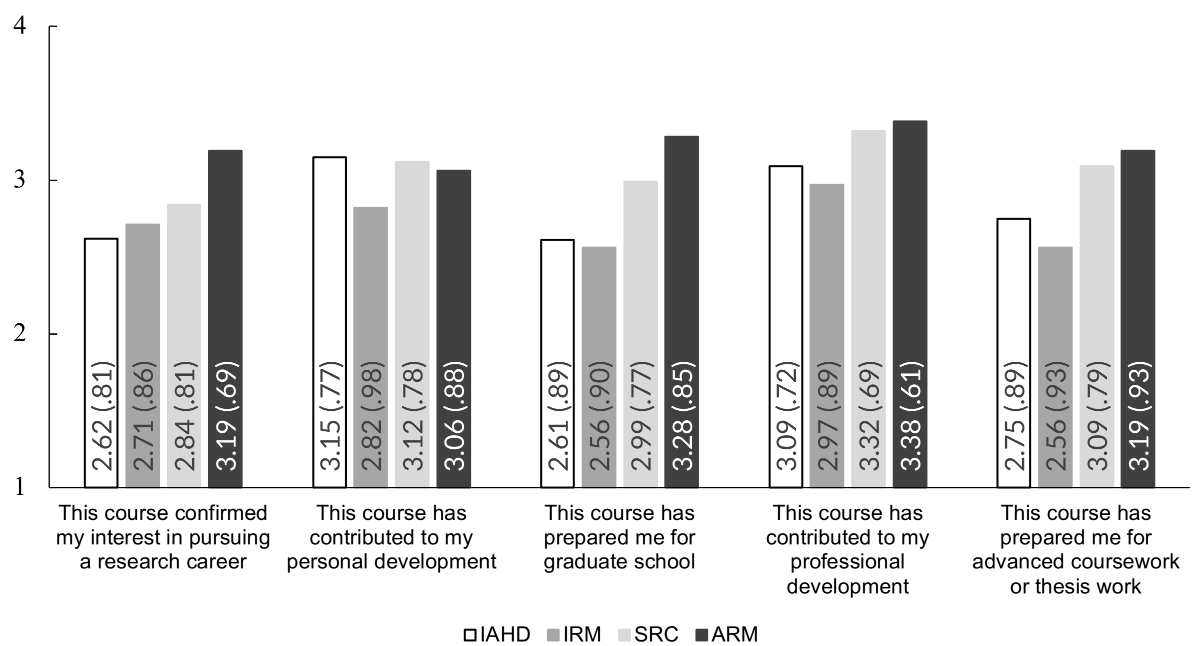
Personal and Skills Gains Ratings. As illustrated in Figure 1, student ratings indicated that IAHD contributed most to their personal and professional development. Interestingly, the biggest gains reported were for comfort working collaboratively as well as ability to work independently (see Figure 2a). Research gains did not differ by URM status. In response to how well IAHD confirmed their interest in pursuing a research career, research program trainees (mean = 2.79, standard error = 0.08) reported higher ratings than non-trainees (mean = 2.43, standard error = 0.10), $t(150) = 2.77$, $p = .006$, $d = 0.40$ (small effect). Students not participating in training programs provided higher gains for writing scientific reports or papers (trainees: mean = 3.31, standard error = 0.14; non-trainees: mean = 3.70, standard error = 0.12; $t(148.4) = -2.09$, $p = .038$, $d = 0.26$ (small effect), ability to work independently (trainees: mean = 3.71, standard error = 0.14; non-trainees: mean = 4.11, standard error = 0.14; $t(147) = -2.04$, $p = .043$, $d = 0.04$ (no meaningful effect)) and understanding what everyday research work is like (trainees: mean = 3.03, standard error = 0.16; non-trainees: mean = 3.68, standard error = 0.14; $t(139.8) = -3.06$, $p = .003$, $d = 0.13$ (no meaningful effect)). A large effect was found for the difference in gains reported for explaining their project to people outside their field between research program trainees (mean = 3.45, standard error = 0.16) and non-trainees (mean = 3.63, standard error = 0.15), although this difference was not statistically significant, $t(140) = -0.81$, $p = .430$, $d = 0.84$ (large effect).

Table 2. Survey Items for Course Components and Topics – Interdisciplinary Approaches to Health Disparities

Survey Item	Mean	Standard Deviation
Course Components		
Final Project	3.39	0.81
Activities	3.21	0.77
Lectures	3.20	1.03
Exams	2.85	0.94
Health Disparities Topics		
Prevalence of Health Disparities	3.65	0.58
Socio-cultural Risks Influencing Health Disparities	3.54	0.63
Environmental Factors Influencing Health Disparities	3.48	0.70
Treatment Interventions for Diverse Groups	3.45	0.75
Ethical Considerations for Health Disparities Research	3.44	0.70
Systemic Risk Factors Influencing Health Disparities	3.42	0.65

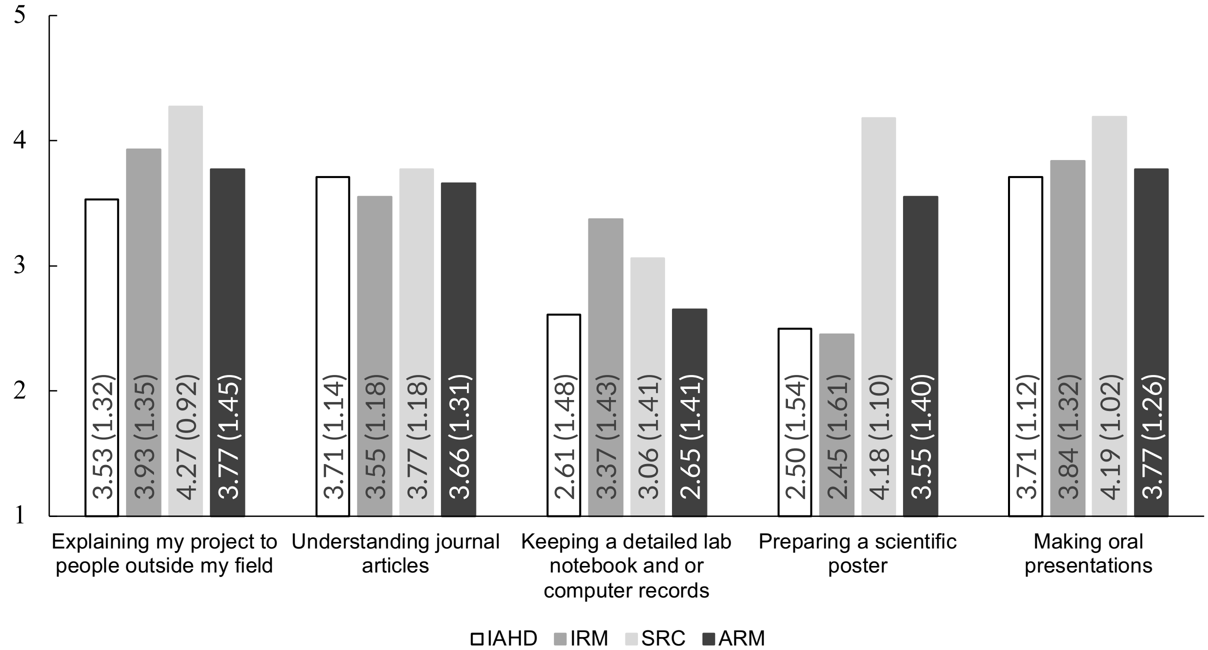
Note. Question stem for the following survey item was "Howmuch did the following support your learning?" Survey items on a 4-point Likert scale: 1 = not at all, 2 = a little, 3 – a good amount, 4 = a great deal.

Figure 1. Survey Items for Personal Gains by Course



Note. Means (with standard deviations in parentheses). Research experiences survey items on a 4-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree.

Figure 2a. Survey Items for Skills Gains by Course



Note. Means (with standard deviations in parentheses). Research gains survey items on a 5-point Likert scale: 1 = no gains, 2 = a little gain, 3 = moderate gain, 4 = good gain, 5 = great gain.

Introduction to Research Methods. *Course Component Ratings.* Table 3 displays students' ratings of main components and topics included in the IRM course. Independent work and oral presentations were rated highest for being supportive of learning. Ratings for all components indicated they supported learning "a good amount." Despite lack of statistical significance, there were several differences by ethnic minority status that had meaningful effect sizes. Responses from URM students (mean = 2.75, standard error = 0.33) indicated larger gains for preparing scientific posters than non-URM students (mean = 2.21, standard error = 0.30), $t(51) = 1.23$, $p = .226$, $d = 0.43$ (small effect), understanding of various research opportunities in the field of biomedical careers (URM students: mean = 3.78, standard error = 0.25; non-URM students: mean = 3.12, standard error = 0.25), $t(59) = 1.87$, $p = .066$, $d = 0.57$ (medium effect), and for understanding what everyday research work is like (URM students: mean = 3.41, standard error = 0.28: non-URM students: mean = 2.80, standard error = 0.23), $t(60) = 1.68$, $p = .099$, $d = 0.51$ (medium effect). No significant differences were found between research trainees and non-trainees.

Table 3. Survey Items for Course Components and Topics – Introductory and Advanced Research Methods

Survey Item	Introductory Research Methods		Advanced Research Methods	
	Mean	Standard Deviation	Mean	Standard Deviation
Course Components				
Lectures	2.92	1.12	3.16	0.85
Independent Work	2.90	0.95	3.62	0.61
Group Work	2.82	1.06	2.33	1.35

Note. Question stem for the following survey item was "How much did the following support your learning?" Survey items on a 4-point Likert scale: 1 = not at all, 2 = a little, 3 = a good amount, 4 = a great deal.

Personal and Skills Gains Ratings. Figure 1 shows that, on average, students agreed that IRM contributed to their professional development. The largest gain was being able to explain their research project to people outside of their field. Compared to non-URM students (mean = 2.51, standard error = 0.14), ratings that the IRM course confirmed their interest in pursuing a research career were higher for URM students (mean = 2.96; standard error = 0.16), $t(60) = 2.101$, $p = .040$, $d = 0.49$ (small effect). Confidence in ability to do well in future research courses was also higher among URM students (mean = 4.04, standard error = 0.26) vs. non-URM students (mean = 3.06, standard error = 0.25), $t(59) = 2.70$, $p = .009$, $d = 0.83$ (large effect). While not statistically significant, there was a small effect for the larger gains in confidence in ability to do well in future research courses by research program trainees (mean = 3.67, standard error = 0.22) vs. non-trainees (mean = 3.11, standard error = 0.35), $t(59) = 1.38$, $p = .172$, $d = 0.46$ (small effect).

Scientific Research Communication. ***Course Component Ratings.*** Table 4 displays student ratings of the SRC course components and topics. Completing independent work and oral presentations seemed to contribute most to learning. Learning about the process of effective writing was the highest rated topic for contributing to learning, while best practices for writing was rated lowest. There were no statistically significant group differences for URM students vs. non-URM students. However, there was a medium effect found for the differences in how much URM students (mean = 3.22, standard error = 0.18) reported that class lectures supported their learning compared to non-URM students (mean = 2.69, standard error = 0.20), $t(59.0) = 1.97$, $p = .053$, $d = 0.52$ (medium effect). Students that were not in research training programs (mean = 3.58, standard error = .07) reported that that the Elements of Scientific Writing session supported their learning more than research trainees (mean = 3.29, standard error = 0.10), $t(158) = -2.49$, $p = .014$, $d = 0.34$ (small effect). Based on effect size, this same pattern was found when comparing the Library Workshop between trainees (mean = 2.81, standard error = 0.14) and non-trainees (mean = 3.12, standard error = 0.09), $t(103.7) = -1.93$, $p = .056$, $d = 0.32$ (small effect).

Table 4. Survey Items for Course Components and Topics - Scientific Research Communication

Survey Item	Mean	Standard Deviation
Course Components		
Independent Work	3.40	0.71
Oral Presentation	3.40	0.75
Group Work	3.13	0.85
Lectures	3.09	0.87
Writing Topics		
Process of Effective Writing	3.50	0.74
Elements of the Research Paper	3.49	0.73
Elements of Scientific Writing	3.46	0.73
Persuasive Writing in Research Proposal Writing	3.45	0.73
Grammar	3.08	0.98
Best Practices for Writing	2.86	0.96

Note. Question stems from the following survey item, "How much did the following support your learning?" Survey items on a 4-point Likert scale: 1=not at all, 2=a little, 3=a good amount, 4=a great deal.

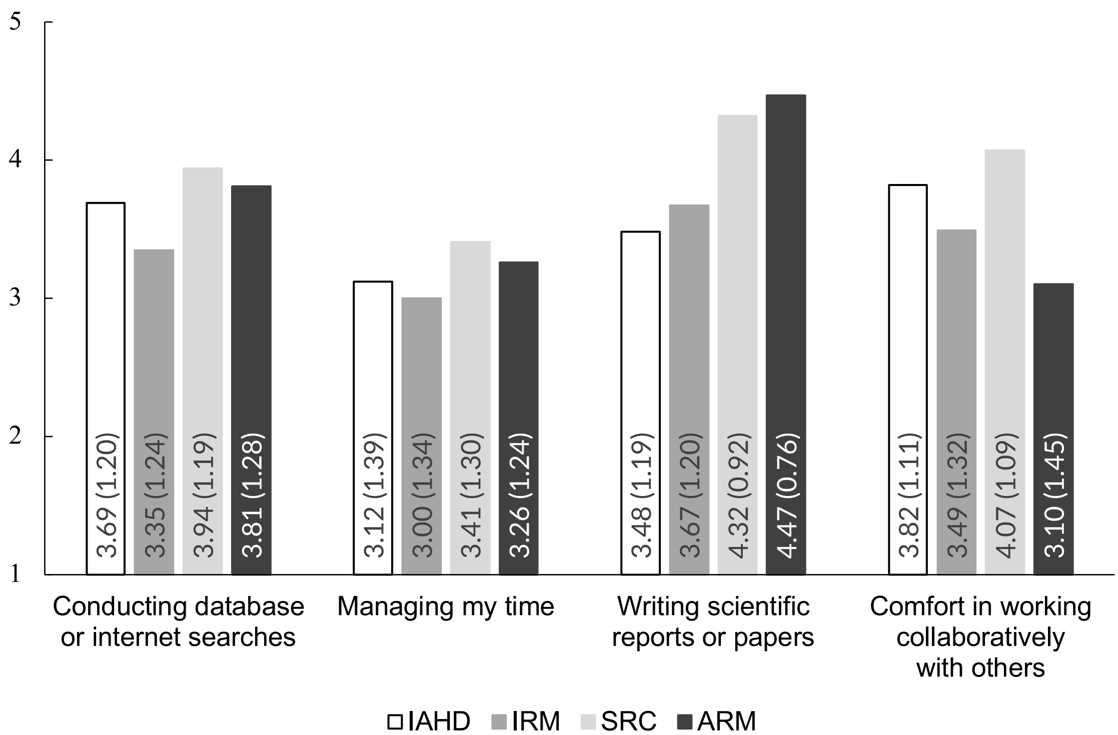
Personal and Skills Gains Ratings. Students felt strongest that the SRC course contributed to their professional development (see Figure 1). Writing scientific reports or papers was reported as having the largest gain, with the lowest gain being keeping a lab notebook or computer records. No differences were found between URM students and non-URM students for research experiences and gains. Research program trainees (mean = 3.15, standard error = 0.09) gave this course higher ratings for confirming their interest in a research career compared to non-trainees (mean = 2.65, standard error = 0.08), $t(159) = 4.00$, $p<.001$, $d = 0.57$ (medium effect). In regard to feeling that SRC prepared them for graduate school, research trainees (mean = 3.17, standard error = 0.10) also reported higher ratings than students who were not in research training programs (mean = 2.87, standard error = 0.08), $t = (159) = 2.497$, $p = .014$, $d = 0.35$ (small effect). Non-trainees' (mean = 3.21, standard error = 0.08) ratings for the item: "This course has contributed to my personal development," were higher than those of trainees (mean = 2.97, standard error = 0.10), $t(159) = 1.98$, $p = .050$, $d = 0.28$ (small effect).

Advanced Research Methods. *Course Component Ratings*. As seen in Table 3, independent work appeared to contribute most to learning in the ARM course. In contrast, group work contributed the least to student learning. There were no significant differences in course component ratings by URM status or for trainee status.

Personal and Skills Gains Ratings. Contribution to professional development was also the highest rated research experience outcome for this course (see Figure 1). The largest research gains were in writing a scientific report (Figure 2b), followed by conducting database or internet searches (Figure 2b). While no statistically significant differences were found between URM students and non-URM students, effect sizes indicated meaningful differences in research gains. URM students (mean = 4.68, standard error = 0.13) reported larger gains in writing scientific reports or papers than non-URM students (mean = 4.15, standard error = 0.25), $t(18.8) = 1.88$, p

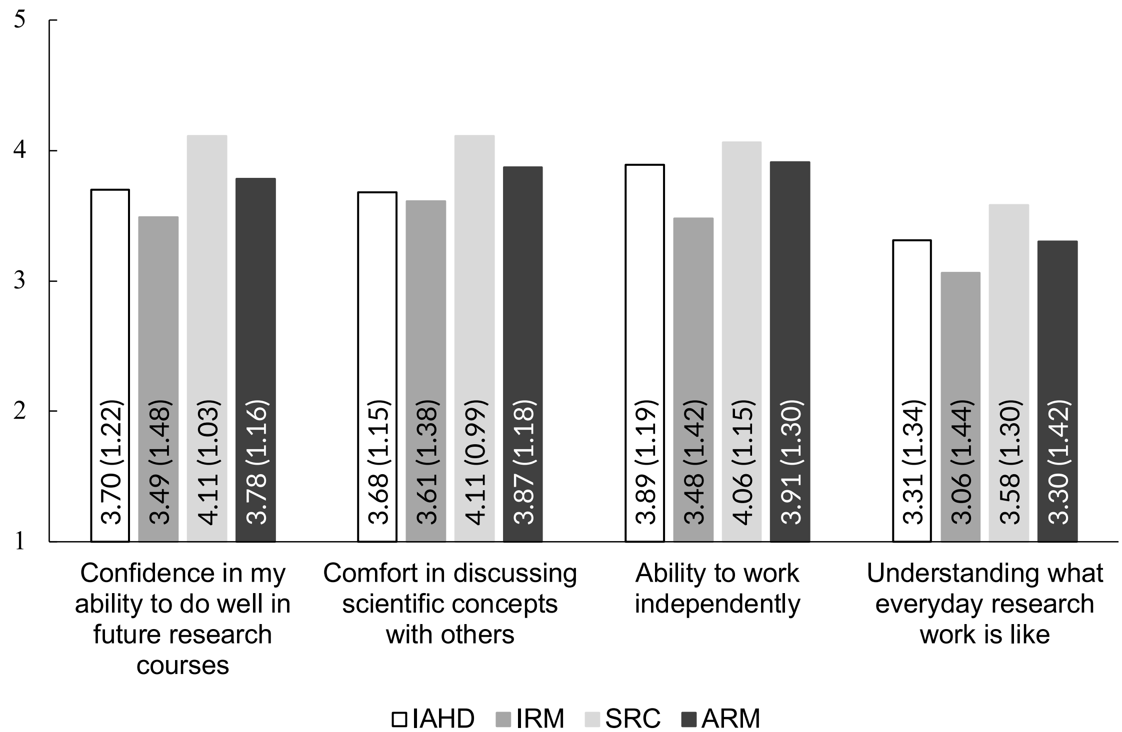
= .076, *d* = 0.62 (medium effect) as well as for ability to identify specific fields of interest within behavioral sciences (URM students: mean = 3.72, standard error = 0.29; non-URM students: mean = 3.23, standard error = 0.36), $t(29) = 1.07$, $p = .292$, $d = .48$ (small effect). Non-URM students (mean = 3.00, standard error = 0.52) reporter larger gains than URM students (mean = 2.44, standard error = 0.32) for keeping a detailed lab notebook and or computer records, $t(24) = -0.99$, $p = .333$, $d = 0.47$ (small effect). Non-URM students (mean = 3.38, standard error = 0.46) also indicated larger gains in comfort in working collaboratively with others compared to URM students (mean = 2.88, standard error = 0.32), $t(27) = -0.94$, $p = .355$, $d = .42$ (small effect). Only one student in the ARM course did not participate in a formal research training program, therefore, no inferential statistics were conducted to compare ARM students participating in research training program versus those that were not.

Figure 2b. Survey Items for Skills Gains by Course (continued)



Note. Means (with standard deviations in parentheses). Research gains survey items on a 5-point Likert scale:1 = no gains, 2 = a little gain, 3 = moderate gain, 4 = good gain, 5 = great gain.

Figure 2c. Survey Items for Skills Gains by Course (continued)



Note. Means (with standard deviations in parentheses). Research gains survey items on a 5-point Likert scale: 1 = no gains, 2 = a little gain, 3 = moderate gain, 4 = good gain, 5 = great gain.

Discussion

The findings are organized in this section by the research question. The three research questions in this study are the following: (1) Which course components and perceived personal and skills gains of the undergraduate research methods courses were rated highest by students?, (2) Are there differences in students' perceptions of the undergraduate research courses between underrepresented minority and non-minority students?, and (3) Are there differences in the students' perceptions of the undergraduate research methods courses between those who did and did not participate in a formal research training program?

Patterns in Student Perceptions of Research-Infused Courses. Patterns emerged across all four courses in undergraduate student perceptions of course components and perceived personal and skills gains. Generally, the application components of the course were rated higher than the instructional components of the course (e.g., lectures and exams). Given that the literature on CUREs is limited in terms of identifying what specific components are most impactful for students (Auchincloss et al., 2014), this finding provides evidence that the application components of CUREs and research-infused courses support student engagement in science. Not surprisingly, reimagining pedagogical approaches remains key to effective science teaching

(Eliason, 2019). For IAHD, the highest-rated course component was the final project, and for SRC, the highest-rated components were independent work and oral presentations. For both IRM and ARM, independent coursework was highly rated.

Among the five aspects of personal gains, the highest-rated experience for three out of the four courses was the contribution of the course to students' professional development. In addition, an interesting longitudinal pattern emerged across the courses. Across most aspects of the research experience – pursuing a research career, preparation for graduate school, professional development, and preparation for advanced coursework and theses – students reported higher gains in personal development as they progressed through the research-infused coursework from IAHD, to IRM, to SRC, and then to ARM. This longitudinal trajectory was similar for URM and non-URM students. This pattern of higher ratings across time suggests that the research experience becomes more meaningful for students as they mature across their undergraduate careers. Prior research supports early exposure for undergraduate students to research as a launching pad to a science career, particularly for URM students (Bangera & Brownell, 2014; Olivares-Donoso & González, 2019). Findings from this study suggest that early and repeated exposure to research through a research-infused curriculum could have an additive effect on science undergraduates.

In terms of skills gains, the highest-rated gains generally aligned with the primary aim of the specific course. For both IAHD and IRM, students reported high gains in understanding journal articles, while SRC students pointed to preparing a scientific poster and making oral presentations, and ARM students rated conducting database/internet searches and reported writing very high. Skills gains in communications were highly rated across all courses; students reported large gains in explaining projects to people outside their field and comfort in discussing scientific concepts with others. Overall, in this study, personal and skills gains in these research-infused courses parallel gains reported in prior research via participation in formal research training programs (Lopatto, 2007). This outcome indicates that course-based strategies may promote skills that contribute to persistence in the science disciplines similar to formal research training programs.

Comparisons Between URM and Non-URM Students. There were few statistically significant differences in students' perceptions of undergraduate research experiences and personal and skills gains between URM students and non-URM students. No statistically significant differences were observed in any of the survey items in IADH, SRC, and ARM, although some non-significant findings yielded moderate effect sizes. In the IRM course, URM students reported, on average, a larger impact of the course on confirming students' interest in pursuing a research career compared to non-URM students. In the IRM course, URM students also reported higher gains in confidence in their ability to do well in future research courses.

In contrast to our findings in this study, prior research from Jones et al. (2010) found that gains in academic outcomes for URM students in formal research training programs were significantly greater than that for non-URM students. However, the focus of this study was on personal and skills gains and not academic outcomes. In addition, the absence of statistically significant differences between URM students and non-URM students in these research-infused courses could be viewed positively. Bangera and Brownell (2014) concluded that CUREs could help close opportunity gaps between URM students and non-URM students. The findings from this study on research-infused courses support Bangera and Brownell's finding on CUREs. In addition to formally defined CUREs, more broadly conceptualized and accessible research-infused courses appear to help close opportunity gaps in the undergraduate science curriculum. Since there were very few statistically significant differences in personal and skills gains between URM students and non-URM students, this indicates that these novel courses did not unintentionally create an opportunity gap. These research-infused courses supported personal and skills gains for URM and non-URM students alike.

Differences Based on Formal Research Training Participation. Formal research training status seemed to have more influence on perceptions of personal gains than URM status, particularly in the IAHD and SRC courses. In both IAHD and SRC, formal research trainees reported significantly higher ratings for the course confirming their interest in pursuing a research career. In SRC, non-trainees reported higher ratings for the course contributing to their personal development. Although some moderate to large effect sizes were observed, no statistically significant differences were observed in IRM, and statistical tests could not be conducted for ARM because 31 out of 32 students were in a formal research program. This finding supports prior research on the impact of formal research training programs on career trajectories (Eagan Jr et al., 2013; Lopatto, 2007). This study is unique in that it examines formal research training programs in conjunction with course-based research efforts. The significant differences in IAHD and SRC courses for formal research trainees suggest that combining a formal research training program and research-infused curriculum creates a stronger research-focused environment.

For gains in skills, statistically, significant findings were observed only in IAHD. For three aspects – writing scientific reports and papers, working independently, and understanding everyday research – students who did not participate in a formal research training program reported significantly higher gains than students in a formal program. No statistically significant differences were observed in IRM and SRC. The significant differences in IAHD courses for non-trainees are not surprising. Since these students are not participating in a formal research training program, it is logical to conclude that they would gain more research skills through these courses than trainees who are gaining these skills in their coursework and research activities.

The pattern of significant and non-significant findings across these research-infused courses are important to consider. The most significant findings were observed in the IAHD course that students complete as sophomores. These findings support Bangera and Brownell (2014) and

Olivares-Donoso (2019) research course experiences that CUREs are particularly effective at engaging students early in their undergraduate careers. Moreover, similar to the non-significant results discussed earlier between URM and non-URM students, non-significant differences between trainees and non-trainees are somewhat encouraging. These non-significant findings indicate that personal and skills gains are similar for trainees and non-trainees alike, particularly at the upper-division level. For institutions that wish to engage students in research and are unable to offer formal research training programs, implementing CUREs and other research-infused courses into the curriculum offer an alternative yet effective approach to addressing inequities in the science pipeline.

Limitations. While this study examined the impact of research-infused courses on personal and skills gains using inferential statistical methods, some limitations in this study are important to acknowledge. The sample comprised of undergraduate students from a public university in southern California. Thus findings may not generalize to students enrolled at other types of universities or in dissimilar regions of the U.S. This study relied on student self-reports of personal and skills gains and was aligned with prior research (Weston & Laursen, 2015). However, concerns related to response bias suggest that future research could utilize other measures of personal and skills gains (e.g., assessment of gains by faculty) or other academic outcomes (e.g., course grades, persistence, and graduation, et cetera).

Further, the wording of certain items may have reduced applicability to different research settings of the students (e.g., some were in wet labs vs. some doing social science field research). For example, "keeping a lab notebook or computer records" may not be a practice used in different types of research labs, and more general wording, such as "keeping data records" may have captured this activity more broadly. Relatedly, some of the research skills were not included in all courses, so low ratings may reflect that students did not receive instruction on a topic, rather than the course not doing a good job of impacting that topic (for example, students in the IAHD course did not create research posters). In addition, this study focused on comparing these outcomes of interest based on URM status and participation in a formal research training program. When examining inequities in the science and engineering workforce, it may be of interest to examine the differential effects of research-infused courses based on gender and first-generation education status. While this study examined 410 students across three academic years, sample sizes were smaller by course, reducing power to find statistically significant effects in some courses, limiting the ability to conduct inferential analysis in one course. Some non-significant findings were observed with moderate to large effect sizes, suggesting that increasing sample size in future studies would be useful. Further, while a large number of analyses were conducted, the error rate was not controlled.

Conclusion

Prior efforts at addressing the persistent demographic disparities in the health-related research workforce and the broader STEM pipeline have focused on engaging undergraduate students through formal research training programs or CUREs. Extant research demonstrates that these approaches effectively eliminate opportunity gaps between URM and non-URM students. However, these formal research training programs are often cost-prohibitive or serve a limited number of students. To broaden the availability of research skills training, the CSULB BUILD Program faculty developed an array of research-infused courses to integrate research and professional skills development directly into the curriculum, opening the door for a larger share of students, including URM students, to engage in the research process. The findings from this study indicate that application components of these research-infused courses support student engagement in the sciences and that these courses contributed to students' professional development and gains in a variety of skills, particularly scientific communication. Non-significant differences observed in personal and skills gains between URM students and non-URM students and significant differences observed between research trainees and non-trainees suggest that research-infused courses have the potential to equitably engage all students throughout their undergraduate careers. The results of this study add to the knowledge base in this subject by expanding beyond formal research training programs and formally-defined CUREs to consider the impact of a research-infused curriculum, which could be more cost-effectively institutionalized by colleges and universities interested in pursuing similar initiatives to eliminate opportunity gaps for student success in the sciences and promoting diversification of the health-related research workforce.

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