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Perspective

Addressing the need to facilitate undergraduate research experiences for community college transfer students in science

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ABSTRACT Community college transfer students face numerous challenges, including gaining access to undergraduate research experiences. In this Perspectives piece, we articulate the benefits of undergraduate research experiences for community college transfer students, some of the common barriers for engaging transfer students in undergraduate research, and how 4-year institutions can address these problems through the development of transfer-specific programs. We specifically discuss the LEAP Scholars program, which we designed for low-income community college transfer students. The LEAP Scholars program helped students learn about undergraduate research through their participation in a science education course-based undergraduate research experience and facilitated student access to undergraduate research experiences in science faculty member research labs.

KEYWORDS community college, 2-year college, transfer, undergraduate research experience, undergraduate research apprenticeship, CURE, course-based undergraduate research experience, student co-authors, science

Despite the fact that nearly half (49%) of bachelor's degree earners in the United States enrolled at some point in courses at community colleges, just 2.1% of doctoral degree earners in science first earned an associate's degree from a community college, meaning that few university faculty attended community colleges themselves (1). While many factors influence this disparity, one barrier could be that students generally have fewer opportunities to participate in undergraduate research at community colleges compared to opportunities afforded to students who spend all years at a 4-year research institution (2). Though research experience is not generally an explicit requirement for attending graduate school in the sciences, the strength of the applicant's research experiences is evaluated in decisions of who is admitted into science graduate programs (3–7). Furthermore, undergraduate research participation predicts enrollment in science graduate degrees (8, 9). Therefore, compared to students who start at 4-year institutions, community college transfer students who did not have opportunities for comparable involvement in undergraduate research experiences may be less competitive applicants for graduate programs and careers in the sciences.

There are many paths an undergraduate student may take that involve some level of enrollment at a community college and subsequent transfer to a 4-year institution. Here, we are considering those students who take the bulk of their lower-division coursework at a community college and then transfer to a 4-year institution to complete their upper-division degree requirements. In this Perspectives piece, we highlight the potential impact of participating in undergraduate research specifically for community college transfer students, describe barriers to their engagement in undergraduate research experiences, discuss how course-based undergraduate research experiences (CUREs) can counteract some of these barriers, and present one model of a specific approach to supporting community college transfer students in undergraduate research.

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UNDERGRADUATE RESEARCH EXPERIENCES ARE A GATEWAY INTO SCIENCE CAREERS

Undergraduate research experiences have traditionally been offered through an apprenticeship model where students become members of a faculty's research program and are mentored by the faculty member or another senior researcher. Such research experience is highly recommended for entrance into professional schools such as medical school (3, 10) and is often considered by admissions committees for entry into research-centered master's and PhD programs in science, especially more elite programs (3–7). Participation in undergraduate research can result in numerous affective and tangible benefits, including improving students' research practices, scientific knowledge, and understanding of the nature of science (11, 12). Research experiences can also support students' self-identity as a scientist, inform students' career goals, and increase persistence in science majors and careers (11–17). Students in undergraduate research experiences are often provided mentorship from faculty and/or senior researchers (e.g., graduate students or postdoctoral researchers) who can provide psychosocial support, increase students' professional networking, and provide letters of recommendation for jobs or graduate applications (11, 14, 14, 17, 18). Given the breadth of potential positive outcomes from participation in research experiences, all undergraduate science students—even those who do not plan to pursue postgraduate degrees with research components—are likely to benefit from research experiences. These experiences have been recommended for all science undergraduates, and there have been calls for efforts to ensure that students who start their degrees at community colleges are included in these experiences (19). Many community college transfer students struggle when making the transition to a 4-year institution: community college transfer students often see dips in their grades (20), feel as though they do not belong in their science major or at their universities (21), and many do not end up graduating with a bachelor's degree (22). Given the known benefits of research, participation in research activities could directly alleviate many of the known challenges that community college transfer students in science face.

BARRIERS FOR COMMUNITY COLLEGE TRANSFER STUDENTS IN UNDERGRADUATE RESEARCH EXPERIENCES

Much attention has been given to increasing undergraduate participation in research experiences for all science majors (19, 23, 24). However, there are many challenges with the goal of equitably and effectively engaging students in these valuable research experiences. First, there are limited undergraduate research positions in faculty member's labs. Since at most universities, there are more science students than undergraduate research positions, faculty researchers have the power to select the undergraduate researchers who they view as the "best" candidates for their lab (25). This selection process privileges students who have more resources to prepare them for such a position, such as extra time, motivation, and understanding the unwritten rules of undergraduate research (26, 27).

Though there has been attention devoted to engaging community college students in research (2, 28), community college science faculty are not typically expected to conduct research as part of their official job description, so few have active research programs that students can participate in (29). Therefore, community college transfer students are often limited to finding research opportunities at 4-year institutions and typically do not start these experiences until they transfer.

However, it can be difficult for transfer students to fit research experiences into their curriculum during their final undergraduate years. Transfer students need to quickly learn what research is, how research can benefit them, and the steps they need to take to find, secure, and engage in an undergraduate research experience (26, 27). Though the majority of students who participate in undergraduate research are in their junior and senior years (30), students who begin at a 4-year university have their earlier years to learn about research opportunities and decide whether they are interested in pursuing a

research experience. These non-transfer students likely have more formalized orientations for conveying information about research and more opportunities in their courses to engage with graduate students or faculty who can either become research mentors or connect them to research mentors. Time to build connections with potential research mentors is critical, given that students who find and secure research positions often do so by talking with their professors, academic advisors, teaching assistants, and peers (27). Given that research positions are often limited and entry into these positions can be competitive, simply having more time to navigate the process of finding a research lab can be extremely valuable. Unfortunately, community college transfer students are on a tight timeline: if they do not immediately try to get a research experience in their first semester—when they are going through the adjustment of a new, larger institution—they may not be suitable candidates for most faculty who want students to join their research labs for multiple years.

Even if community college transfer students can overcome these barriers to accessing undergraduate research, they still may be disadvantaged in their ability to fully benefit from these experiences. For example, if a transfer student, during their first term at a 4-year university, is able to quickly secure a research position in a faculty member's lab and begins by their second term of their junior year, they have a maximum of 1.5 years for their research experience if they plan on graduating at the end of their 2-year post-transfer. Students reap more benefits the longer they engage in an undergraduate research experience (31–36). For example, shorter research experiences leave students with fewer opportunities to network, attend conferences, and present their research, and less likely to result in inclusion as a coauthor on scientific publications (37). Additionally, students with significant and high-quality research experiences are more competitive candidates for graduate and professional programs (3, 6). Not only do faculty perceive that students' problem-solving, intellectual curiosity, and independence benefit from additional time in research (35), but longer undergraduate research experiences are predictive of students' performance in STEM PhD programs (38).

Compounding this problem is the fact that community college transfer students, on average, are disproportionately from lower socioeconomic backgrounds than students who started their college experiences at a 4-year institution (39). Undergraduate research positions are often unpaid, and even if students have opportunities to be paid as researchers, they are often expected to first volunteer or do research for course credit for multiple terms. This system naturally favors students from more financially privileged backgrounds who can afford to spend their extracurricular time in unpaid work. Community college students who are from low-income backgrounds may need to balance time spent in research with higher-paid outside employment, spend more time commuting to the university campus from areas with more affordable housing, and have increased family responsibilities (40). This means in addition to having a shorter length of overall participation in a research experience, low-income transfer students likely have limited hours to spend in unpaid (or underpaid) research positions on a weekly basis. This is a likely reason why low-income students are significantly less likely to be included as co-authors on scientific publications from their undergraduate research experience compared to higher-income students (37). Co-authorship on scientific publications can be a significant advantage for applicants to postgraduate programs in science or medicine, and if participation in research does not equitably offer this opportunity to low-income community college transfer students, these students are likely systematically disadvantaged in pursuing future science careers despite their research experiences.

COURSE-BASED UNDERGRADUATE RESEARCH EXPERIENCES CAN MITIGATE SOME BARRIERS TO RESEARCH ACCESS

One approach to counteract the hurdles implicit in trying to obtain an undergraduate research experience in a faculty member's lab is to provide students with authentic research experiences in the context of a formal course (25). Course-based undergraduate research experiences engage students in authentic scholarship of a discipline and have

been shown to yield many of the same benefits as independent research experiences in faculty labs (41, 42). Some CUREs have been developed at community colleges, which help address the disparity of research experiences for community college students (2, 43). However, as an academic community, we cannot burden community colleges with closing the research participation gap for community college students who will transfer to 4-year institutions. Access to research funding is often limited for community colleges, and most community college faculty are not expected to do research as part of their formal jobs (2). In contrast, faculty at 4-year institutions are often able to build upon the research done in their lab (44–47), while sometimes leveraging the expertise of graduate students and postdocs to aid in the administration of the CURE and related research. Therefore, we posit that 4-year institutions should share in the responsibility of ensuring that research opportunities are offered to undergraduates, particularly community college transfer students, at scale.

CUREs available to community college transfer students as a first-semester course after transferring to the 4-year university stand to provide a unique array of benefits. First, a CURE offered during a student's first semester at a 4-year institution eliminates the need for transfer students to know the "unwritten rules" about engaging in research (27), allows students to start a research experience immediately so they can maximize the time spent in research, and can be designed such that students receive formal course credit for the CURE so it is not something that they have to add on to their normal coursework. Additionally, CUREs are known to build a sense of belonging and community among participants (48–51). Therefore, engaging in a CURE in a transfer student's first semester may help protect against transfer shock at the 4-year institution. However, CUREs alone may not fulfill research needs for students interested in pursuing postgraduate education (e.g., medical school and PhD programs)—both in terms of duration and in the possibility that postgraduate programs may weigh independent undergraduate research experiences in faculty research labs more favorably than CUREs. Therefore, facilitating access to mentored independent research experiences may also be key to fully supporting community college transfer students.

OUR APPROACH: THE LEAP PROGRAM, A PLAN TO IMMERSE INCOMING COMMUNITY COLLEGE TRANSFER STUDENTS IN UNDERGRADUATE RESEARCH

We designed a four-semester long program specifically for supporting community college transfer students in entering and succeeding in undergraduate research experiences after their transfer to a 4-year institution. The development of this program aimed to address two specific challenges: (i) science transfer students at our university were participating in undergraduate research experiences at lower rates and (ii) transfer students may not participate in research because of their need to work outside jobs. Funded by the NSF S-STEM (Scholarships in STEM) program to specifically support low-income, high-achieving students, we designed an approach to quickly introduce students to research and help students maximize benefits from their research experiences while providing them with scholarships. To participate in the program, students needed a minimum community college GPA of 3.0, had to demonstrate financial need, and be majoring in a science discipline. We did not accept applicants who had only taken community college classes as supplemental to their high school curriculum. Most students did not have any prior research experience, and prior research experience was not considered for selection into the program. In some years, we conducted interviews with potential student applicants, but any student who applied, met the minimum selection criteria, and completed an interview was accepted. The program lasted for 7 years, serving a total of 50 students in five cohorts. The S-STEM grant funded students for at least four semesters as they completed their science degree at the university and continued to meet the program requirements (i.e., majoring in a science discipline and participating in program activities). In many cases, the grant additionally funded scholars

who needed an additional semester or two before graduation, which is common for community college transfer students.

The program consisted of three activities, described below.

Science education CURE

During their first term in the program, scholars participated in a three-credit CURE that engaged them in a real science education research project that they would continue to participate in for the remainder of their time in the program as a one-credit course (52). We chose to situate the CURE within undergraduate science education research because it exposed students to science education literature and caused them to think critically about the decisions that they and others make that impact their learning and collegiate experiences, including their own experiences in undergraduate research experiences. Additionally, some science education research methodologies are relatively accessible to novice researchers.

Independent research experiences

After students learned about what research was and the associated benefits as part of the CURE, they identified potential faculty research mentors related to their own scientific disciplines. We then connected students with mentors and guided students through the process of establishing these student-mentor relationships with the expectation that they would work with that research mentor for the next three semesters.

Receiving and then providing mentoring

Near-peer mentoring, where students who have recently navigated an experience act as role models and provide support and mentorship to incoming students, is an approach known to benefit the scientific development of both student mentors and their mentees (53, 54). The near-peer mentoring approach can provide mentees with academic and psychosocial support (54) while allowing mentors to further develop their confidence and professional skills (53). In the LEAP program, incoming transfer students were paired with a near-peer mentor (a second-year LEAP scholar) and met throughout the year to discuss their academic and research progress as mentees navigated their first post-transfer year. As students moved into their second year in the LEAP program, they were in turn responsible for mentoring the incoming cohort of students. Peer mentors were tasked with providing instrumental support to the incoming scholars in the CURE since they worked on related research projects. Additionally, senior students voluntarily provided integral psychosocial support for their junior cohort, helping them to navigate common challenges that they themselves overcame just the year before.

We called this program the "LEAP" Scholars with the LEAP acronym highlighting the focus of each of the four semesters: **L**earning about Research (taking a three credit science education CURE their first semester and a one credit CURE each subsequent term), **E**ntering research (starting their independent scientific research experience in a faculty lab in the second semester), **A**dvising research (beginning to serve as peer mentors to the next cohort of students), and **P**roducing research (both finalizing the science education projects and presenting their independent scientific research experiences at a local poster session) (Fig. 1).

How did the science education cure benefit community college transfer students and the research community?

There are three primary ways we noted that the LEAP Scholars benefited from the CURE.

Tangible research products

Because the science education CUREs were backward designed to maximize the likelihood that the research project would succeed (55), every LEAP cohort was able

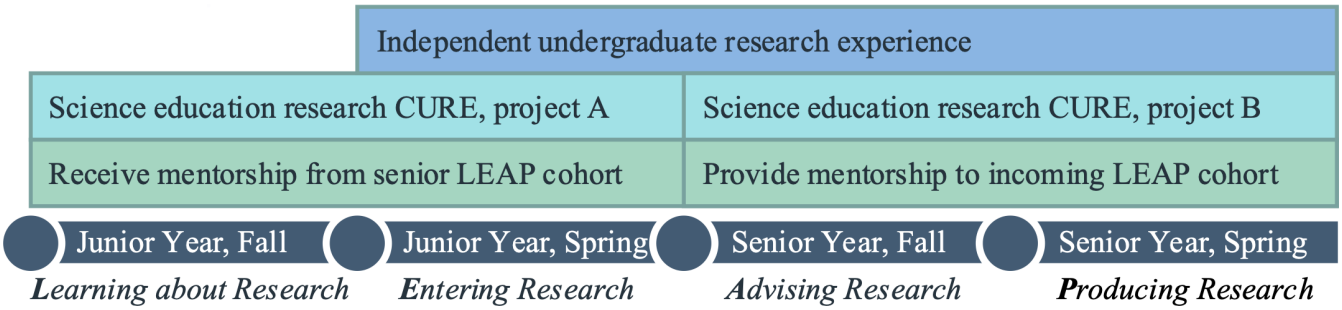

FIG 1 LEAP Scholars program timeline. The top (dark blue) band represents participation in undergraduate scientific research experience in a faculty member's lab, the middle (light blue) band represents participation in the science education CURE, and the bottom (green) band represents receiving or providing peer mentorship.

to publish the findings that resulted from their CURE research project in a peer-reviewed journal (Table 1). In total, 40 LEAP scholars were included as co-authors on at least one publication since they intellectually contributed to the research (56). Some students highlighted these publications when they applied (and were accepted) to medical and graduate schools. Some LEAP scholars only completed a single term, and these individuals did not participate sufficiently in the projects to warrant co-authorship.

Increased metacognition about maximizing one's research experience

Each cohort was expected to conduct a science education CURE research project on the topic of undergraduate research experiences. Students agreed on one question for their cohort to focus on, and we observed that they became more metacognitive about how to maximize their own research experiences. For example, one cohort noticed the scant literature on why students leave research and chose to examine what causes undergraduates to exit their research opportunities prematurely. Scholars expressed that their research topic helped them to later recognize common challenges in their independent research experiences (e.g., being given too little structure early on in research), giving them the foresight to troubleshoot the issues and persist in their experience.

Affective gains

Although we did not have the statistical power to systematically measure affective gains or student retention owing to the small size of each cohort, we frequently heard from students that they felt more like scientists after engaging in the CURE and that the LEAP program was integral to the successful completion of their undergraduate degrees. They expressed the sense of ownership they felt for their project, noticing how our research ideas changed because of their feedback and how one individual's comment could alter

TABLE 1 Summary of LEAP publications and student co-authorship

Topic	LEAP student co-authors[a]	Citation
Study 1: A survey of 768 undergraduate researchers at 25 research-intensive institutions to explore the factors that students consider when deciding whether to stay in or leave their research experiences.	14	(57)
Study 2: An expansion of Study 1. A survey of 1,262 undergraduate researchers from students at 25 public R1s, 12 private R1s, 30 master's-granting institutions, and 20 primarily undergraduate institutions to explore how institution type predicts students' decisions to stay in or leave their research experiences.	17	(58)
Study 3: A literature review (conducted remotely during the COVID-19 pandemic) to examine which student characteristics and identities are reported and analyzed in education research studies on student outcomes from undergraduate research experiences.	17	(59)
Study 4: An interview study to understand the experiences of low-income students who participate in independent undergraduate research experiences in the natural sciences.	5	(40)

[a]In total, 40 unique LEAP student co-authors across all four publications.

the direction of a project. Furthermore, the CURE built community among students, with many ascribing their persistence at the university to the strong support system they built within the CURE. These anecdotally observed outcomes are aligned with research demonstrating that participation in similar support programs can be beneficial in supporting students' sense of belonging and retention in degrees (60).

The nature of the CURE benefited the LEAP Scholar community because of the intimate collaboration the program fostered among diverse researchers. The community college transfer students brought unique skill sets, backgrounds, and perspectives to the research projects (61, 62). Informed by their experiences and perspectives, students repeatedly brought ideas into the projects that the CURE instructors had not anticipated. These ideas were incorporated at every stage of the process: from generating initial research ideas to validation of the surveys used to collect data, to analyzing and interpreting data through their lived experiences. In this manner, the diversity of the group not only helped to counteract the inherent biases of the larger research team (63), but it allowed for a more robust approach to research with varied perspectives.

Finally, the research that was conducted through this program has changed what we know about undergraduate research experiences. Namely, despite all the purported benefits of undergraduate research, 50% of students across institution types consider leaving their research experience (57, 58). Students make decisions about whether to stay or leave based on factors including their lab environment, research mentors, and whether they felt they were benefiting from the experience. We also found that few studies on outcomes of undergraduate research experiences examine student identities beyond race and gender; so the low-income students and community college students on our research team saw that we were asking them to extrapolate data from a population of students in the literature who may have very different lived experiences compared to them (59). This led to an interview study of the experiences of low-income undergraduate researchers, where we identified that participation in research can be a costly activity for low-income students due to factors including outside employment, commute, family responsibilities, and food and housing insecurity (40). Research mentors play a pivotal role in mitigating or exacerbating these barriers to undergraduate research participation for low-income students (40). In summary, these students were able to contribute intellectually to the projects, and the projects were made better by having the input of such a large, diverse research team.

CALL TO ACTION: UNIVERSITIES NEED TO BE ATTENTIVE TO RESEARCH INEQUITIES FOR COMMUNITY COLLEGE TRANSFER STUDENTS

If starting a degree at a community college and later transferring to obtain a bachelor's degree in science is a path intended to prepare students to be competitive applicants for future degree programs and science careers, we need to think about how we can ensure that transfer students are receiving the same access to valuable experiences such as participation in undergraduate research. Although there has been much attention placed on reforming introductory-level programs, including by integrating CUREs into the curriculum (64), a lack of equivalent focus for incoming transfer students may exacerbate gaps in research preparation between students who start their academic careers at universities compared to community colleges. For example, if students starting at 4-year universities engage in CUREs in their first year and are subsequently able to enter faculty research labs in their second year, they will be far ahead of community college transfer students who transfer in their third year without research experience. Therefore, focusing program improvements and curricular changes on first-year students at 4-year institutions, while valuable, can inadvertently widen gaps for community college transfer students.

To provide an equitable undergraduate education, we posit that universities must be attentive to the needs of community college transfer students. There have been efforts to develop CUREs at community colleges [e.g., references (65, 66)] and increase community college students' access to research, sometimes in partnership with 4-year

institutions. In some cases, departments or individual faculty at 4-year institutions actively connect with local two-year colleges to recruit community college students into research internships at the 4-year institution (67). Larger partnerships leverage feeder community colleges where many students transfer to the same 4-year research institution and offer transfer support, mentorship, and cohort-building activities and research opportunities for community college students pre- and post-transfer (68). Additionally, some short-term research internships funded by the National Science Foundation's Research Experiences for Undergraduates program specifically recruit community college students.

Even with these efforts, the lack of existing research infrastructure at community colleges means that students are still unlikely to have equivalent research opportunities as their peers who start their degrees at 4-year institutions. Four-year universities need to find ways to engage community college transfer students in research through efforts such as developing CUREs specific for community college transfer students, implementing upper-level CUREs open to anyone, or facilitating processes for pairing community college transfer students with research mentors to do independent research. One approach to accomplish this is to develop targeted programs, such as the LEAP program, to provide these research experiences for transfer students. Many universities have programs to support transfer students who are interested in research and take varied approaches to providing this support—for other examples, see programs described by Chamely-Wiik et al. (69), Gamage et al. (70), and Zuckerman et al. (71). The LEAP Program represents just one of a myriad of possible approaches, but it does have the unique advantage of giving students not one but two extended research experiences. We encourage universities to take the steps to invest in their community college students through formalized programs and facilitated research experiences, which could be through a science education research CURE.

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REFERENCES

1. NSC Research Center. 2017. From community college to graduate and professional degrees - 2017. National Student Clearinghouse Research Center. Available from: https://nscresearchcenter.org/snapshotreport-from-community-college-to-graduate-and-professional-degrees30
2. Hewlett JA. 2018. Broadening participation in undergraduate research experiences (UREs): the expanding role of the community college. CBE Life Sci Educ 17:es9. https://doi.org/10.1187/cbe.17-11-0238
3. Cavanagh A, Owais S, Syed SA, Zhang A, Van Lieshout RJ. 2023. Diversity in MD-PhD programs and factors affecting admission and completion among minoritized groups: a scoping review. Acad Med 98:410–419. https://doi.org/10.1097/ACM.0000000000005010
4. Jones A, Schuhmann P, Soques D, Witman A. 2020. So you want to go to graduate school? Factors that influence admissions to economics PhD programs. J Econ Educ 51:177–190. https://doi.org/10.1080/00220485.2020.1731385
5. Michel RS, Belur V, Naemi B, Kell HJ. 2019. Graduate admissions practices: a targeted review of the literature. ETS Res Rep Ser 2019:1–18. https://doi.org/10.1002/ets2.12271
6. Posselt JR. 2014. Toward inclusive excellence in graduate education: constructing merit and diversity in PhD admissions. Am J Educ (Chic Ill) 120:481–514. https://doi.org/10.1086/676910
7. Roberts SF, Pyfrom E, Hoffman JA, Pai C, Reagan EK, Light AE. 2021. Review of racially equitable admissions practices in STEM doctoral programs. Educ Sci 11:270. https://doi.org/10.3390/educsci11060270
8. Hathaway RS, Nagda A, Gregerman SR. 2002. The relationship of undergraduate research participation to graduate and professional education pursuit: an empirical study. J Coll Stud Dev 43:1–18.
9. Tai RH, Kong X, Mitchell CE, Dabney KP, Read DM, Jeffe DB, Andriole DA, Wathington HD. 2017. Examining summer laboratory research apprenticeships for high school students as a factor in entry to MD/PhD programs at matriculation. CBE Life Sci Educ 16:ar37. https://doi.org/10.1187/cbe.15-07-0161
10. Association of American Medical Colleges. 2023. Official guide to medical school admissions: how to prepare for and apply to medical school. Washington, DC. Available from: https://store.aamc.org/2023-official-guide-to-medical-school-admissions-how-to-prepare-for-and-apply-to-medical-school.html
11. Laursen S, Hunter A-B, Seymour E, Thiry H, Melton G. 2010. Undergraduate research in the sciences: engaging students in real science. Wiley, San Fransisco, CA.
12. Lopatto D. 2007. Undergraduate research experiences support science career decisions and active learning. CBE Life Sci Educ 6:297–306. https://doi.org/10.1187/cbe.07-06-0039
13. Eagan MK, Hurtado S, Chang MJ, Garcia GA, Herrera FA, Garibay JC. 2013. Making a difference in science education: the impact of undergraduate research programs. Am Educ Res J 50:683–713. https://doi.org/10.3102/0002831213482038
14. Estrada M, Hernandez PR, Schultz PW. 2018. A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers. CBE Life Sci Educ 17:ar9. https://doi.org/10.1187/cbe.17-04-0066
15. Pfeifer MA, Zajic CJ, Isaacs JM, Erickson OA, Dolan EL. 2024. Beyond performance, competence, and recognition: forging a science researcher identity in the context of research training. IJ STEM Ed 11:19. https://doi.org/10.1186/s40594-024-00479-2
16. Robnett RD, Chemers MM, Zurbriggen EL. 2015. Longitudinal associations among undergraduates' research experience, self-efficacy, and identity. J Res Sci Teach 52:847–867. https://doi.org/10.1002/tea.21221
17. Seymour E, Hunter A-B, Laursen SL, DeAntoni T. 2004. Establishing the benefits of research experiences for undergraduates in the sciences: first findings from a three-year study. Sci Educ 88:493–534. https://doi.org/10.1002/sce.10131
18. Linn MC, Palmer E, Baranger A, Gerard E, Stone E. 2015. Education. Undergraduate research experiences: impacts and opportunities. Science 347:1261757. https://doi.org/10.1126/science.1261757
19. Olson S, Riordan DG. 2012. Engage to excel: producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. In Report to the president. Executive office of the president
20. Rhine TJ, Milligan DM, Nelson LR. 2000. Alleviating transfer shock: creating an environment for more successful transfer students. Comm Coll J Res Pract 24:443–453. https://doi.org/10.1080/-10668920050137228
21. Strayhorn TL. 2018. College students' sense of belonging. Routledge, NY.
22. Jenkins D, Fink J. 2016. Tracking transfer: new measures of institutional and state effectiveness in helping community college students attain bachelor's degrees
23. Brewer C, Smith D. 2011. Vision and change in undergraduate biology education: a call to change. American Association for the Advancement of Science, Washington, DC.
24. National Academies of Sciences, Engineering, and Medicine. 2017. Undergraduate research experiences for STEM students: successes, challenges, and opportunities. National Academies Press, Washington, DC.
25. Bangera G, Brownell SE. 2014. Course-based undergraduate research experiences can make scientific research more inclusive. CBE Life Sci Educ 13:602–606. https://doi.org/10.1187/cbe.14-06-0099
26. Busch C, Nadile E, Mohammed T, Gin L, Brownell S, Cooper K. 2024. The scientific rules, roles, and values that life sciences graduate students want to see upheld by undergraduate researchers. JRST. https://doi.org/10.1002/tea.21965
27. Cooper KM, Cala JM, Brownell SE. 2021. Cultural capital in undergraduate research: an exploration of how biology students operationalize knowledge to access research experiences at a large, public research-intensive institution. IJ STEM Ed 8:6. https://doi.org/10.1186/s40594-020-00265-w
28. Cejda BD, Hensel N. 2009. An overview of undergraduate research in community colleges. Council on Undergraduate Research, Washington, DC.
29. Chen Musgrove MM, Nied S, Cooley A, Schinske JN, Corwin LA. 2022. Engaging with CC Bio INSITES: experiences of barriers, supports, and belonging in community college faculty participating in biology education research. CBE Life Sci Educ 21:ar16. https://doi.org/10.1187/cbe.21-09-0246
30. Mahatmya D, Morrison J, Jones RM, Garner PW, Davis SN, Manske J, Berner N, Johnson A, Ditty J. 2017. Pathways to undergraduate research experiences: a multi-institutional study. Innov High Educ 42:491–504. https://doi.org/10.1007/s10755-017-9401-3
31. Adedokun OA, Parker LC, Childress A, Burgess W, Adams R, Agnew CR, Leary J, Knapp D, Shields C, Lelievre S, Teegarden D. 2014. Effect of time on perceived gains from an undergraduate research program. CBE Life Sci Educ 13:139–148. https://doi.org/10.1187/cbe.13-03-0045
32. Daniels H, Grineski SE, Collins TW, Morales DX, Morera O, Echegoyen L. 2016. Factors influencing student gains from undergraduate research experiences at a hispanic-serving institution. CBE Life Sci Educ 15:ar30. https://doi.org/10.1187/cbe.15-07-0163
33. Prunuske AJ, Wilson J, Walls M, Clarke B. 2013. Experiences of mentors training underrepresented undergraduates in the research laboratory. CBE Life Sci Educ 12:403–409. https://doi.org/10.1187/cbe.13-02-0043
34. Thiry H, Weston TJ, Laursen SL, Hunter A-B. 2012. The benefits of multi-year research experiences: differences in novice and experienced students' reported gains from undergraduate research. CBE Life Sci Educ 11:260–272. https://doi.org/10.1187/cbe.11-11-0098
35. Zydney AL, Bennett JS, Shahid A, Bauer K. 2002. Faculty perspectives regarding the undergraduate research experience in science and engineering. J Eng Edu 91:291–297. https://doi.org/10.1002/j.2168-9830.2002.tb00706.x
36. Zydney AL, Bennett JS, Shahid A, Bauer KW. 2002. Impact of undergraduate research experience in engineering. J Eng Edu 91:151–157. https://doi.org/10.1002/j.2168-9830.2002.tb00687.x

37. Grineski S, Daniels H, Collins T, Morales DX, Frederick A, Garcia M. 2018. The conundrum of social class: disparities in publishing among STEM students in undergraduate research programs at a Hispanic majority institution. Sci Educ 102:283–303. https://doi.org/10.1002/sce.21330
38. Gilmore J, Vieyra M, Timmerman B, Feldon D, Maher M. 2015. The relationship between undergraduate research participation and subsequent research performance of early career STEM graduate students. J Higher Educ 86:834–863. https://doi.org/10.1080/00221546.2015.11777386
39. McPherson MS, Schapiro MO. 1994. College choice and family income: changes over time in the higher education destinations of students from different income backgrounds. Department of Economics, Williams College
40. Goodwin EC, Dereadt S, Goode J, Kalfus B, Khanania G, Pang L. Under review. Exploring how low-income students navigate inequities in undergraduate research experiences
41. Brownell SE, Kloser MJ. 2015. Toward a conceptual framework for measuring the effectiveness of course-based undergraduate research experiences in undergraduate biology. Stud Higher Educ 40:525–544. https://doi.org/10.1080/03075079.2015.1004234
42. Corwin LA, Graham MJ, Dolan EL. 2015. Modeling course-based undergraduate research experiences: an agenda for future research and evaluation. CBE Life Sci Educ 14:es1. https://doi.org/10.1187/cbe.14-10-0167
43. Hanauer DI, Graham MJ, Betancur L, Bobrownicki A, Cresawn SG, Garlena RA, Jacobs-Sera D, Kaufmann N, Pope WH, Russell DA, Jacobs WR Jr, Sivanathan V, Asai DJ, Hatfull GF, SEA-PHAGES. 2017. An inclusive research education community (iREC): impact of the SEA-PHAGES program on research outcomes and student learning. Proc Natl Acad Sci U S A 114:13531–13536. https://doi.org/10.1073/pnas.1718188115
44. Cooper KM, Blattman JN, Hendrix T, Brownell SE. 2019. The impact of broadly relevant novel discoveries on student project ownership in a traditional lab course turned CURE. CBE Life Sci Educ 18:ar57. https://doi.org/10.1187/cbe.19-06-0113
45. Goodwin EC, Anokhin V, Gray MJ, Zajic DE, Podrabsky JE, Shortlidge EE. 2021. Is this science? Students' experiences of failure make a research-based course feel authentic. CBE Life Sci Educ 20:ar10. https://doi.org/10.1187/cbe.20-07-0149
46. Mohammed TF, Nadile EM, Busch CA, Brister D, Brownell SE, Claiborne CT, Edwards BA, Wolf JG, Lunt C, Tran M, Vargas C, Walker KM, Warkina TD, Witt ML, Zheng Y, Cooper KM. 2021. Aspects of large-enrollment online college science courses that exacerbate and alleviate student anxiety. CBE Life Sci Educ 20:ar69. https://doi.org/10.1187/cbe.21-05-0132
47. Nadile EM, Williams KD, Wiesenthal NJ, Stahlhut KN, Sinda KA, Sellas CF, Salcedo F, Rivera Camacho YI, Perez SG, King ML, Hutt AE, Heiden A, Gooding G, Gomez-Rosado JO, Ford SA, Ferreira I, Chin MR, Bevan-Thomas WD, Barreiros BM, Alfonso E, Zheng Y, Cooper KM. 2021. Gender differences in student comfort voluntarily asking and answering questions in large-enrollment college science courses. J Microbiol Biol Educ 22:e00100-21. https://doi.org/10.1128/jmbe.00100-21
48. Connors PK, Lanier HC, Erb LP, Varner J, Dizney L, Flaherty EA, Duggan JM, Yahnke CJ, Hanson JD. 2021. Connected while distant: networking CUREs across classrooms to create community and empower students. Integr Comp Biol 61:934–943. https://doi.org/10.1093/icb/icab146
49. Goodwin EC, Cary JR, Phan VD, Therrien H, Shortlidge EE. 2023. Graduate teaching assistants impact student motivation and engagement in course-based undergraduate research experiences. J Res Sci Teach 60:1967–1997. https://doi.org/10.1002/tea.21848
50. Malotky MKH, Mayes KM, Price KM, Smith G, Mann SN, Guinyard MW, Veale S, Ksor V, Siu L, Mlo H, Young AJ, Nsonwu MB, Morrison SD, Sudha S, Bernot KM. 2020. Fostering inclusion through an interinstitutional, community-engaged, course-based undergraduate research experience. J Microbiol Biol Educ 21:21.1.31. https://doi.org/10.1128/jmbe.v21i1.1939
51. Merkle JA, Devergne O, Kelly SM, Croonquist PA, Evans CJ, Hwalek MA, Straub VL, Hamill DR, Peister A, Puthoff DP, Saville KJ, Siders JL, Villanueva Gonzalez ZJ, Wittke-Thompson JK, Bieser KL, Stamm J, Vrailas-Mortimer AD, Kagey JD. 2023. Fly-CURE, a multi-institutional CURE using *Drosophila*, increases students' confidence, sense of belonging, and persistence in research. J Microbiol Biol Educ 24:e00245-22. https://doi.org/10.1128/jmbe.00245-22
52. Cooper KM, Brownell SE. 2018. Developing course-based research experiences in discipline-based education research: lessons learned and recommendations. J Microbiol Biol Educ 19:jmbe-19-88. https://doi.org/10.1128/jmbe.v19i2.1567
53. Tenenbaum LS, Anderson MK, Jett M, Yourick DL. 2014. An innovative near-peer mentoring model for undergraduate and secondary students: STEM focus. Innov High Educ 39:375–385. https://doi.org/10.1007/s10755-014-9286-3
54. Zaniewski AM, Reinholz D. 2016. Increasing STEM success: a near-peer mentoring program in the physical sciences. IJ STEM Ed 3:14. https://doi.org/10.1186/s40594-016-0043-2
55. Cooper KM, Soneral PAG, Brownell SE. 2017. Define your goals before you design a CURE: a call to use backward design in planning course-based undergraduate research experiences. J Microbiol Biol Educ 18:18.2.30. https://doi.org/10.1128/jmbe.v18i2.1287
56. Turner AN, Challa AK, Cooper KM. 2021. Student perceptions of authoring a publication stemming from a course-based undergraduate research experience (CURE). CBE Life Sci Educ 20:ar46. https://doi.org/10.1187/cbe.21-02-0051
57. Cooper KM, Gin LE, Akeeh B, Clark CE, Hunter JS, Roderick TB, Elliott DB, Gutierrez LA, Mello RM, Pfeiffer LD, Scott RA, Arellano D, Ramirez D, Valdez EM, Vargas C, Velarde K, Zheng Y, Brownell SE. 2019. Factors that predict life sciences student persistence in undergraduate research experiences. PLoS One 14:e0220186. https://doi.org/10.1371/journal.pone.0220186
58. Gin LE, Clark CE, Elliott DB, Roderick TB, Scott RA, Arellano D, Ramirez D, Vargas C, Velarde K, Aeschliman A, Avalle ST, Berkheimer J, Campos R, Gerbasi M, Hughes S, Roberts JA, White QM, Wittekind E, Zheng Y, Cooper KM, Brownell SE. 2021. An exploration across institution types of undergraduate life sciences student decisions to stay in or leave an academic-year research experience. CBE Life Sci Educ 20:ar47. https://doi.org/10.1187/cbe.21-04-0108
59. Goodwin EC, Gin LE, Aeschliman A, Afoakwa AK, Allred BA, Avalle ST, Bell A, Berkheimer J, Brzezinski H, Campos R, Emerson H, Hess SC, Montelongo AM, Noshirwani N, Shelton WL, Valdez EM, White J, White Q, Wittekind E, Cooper KM, Brownell SE. 2024. Who is represented in the research on undergraduate research experiences in the natural sciences? A review of literature. CBE Life Sci Educ 23:ar28. https://doi.org/10.1187/cbe.23-07-0137
60. Shortlidge EE, Gray MJ, Estes S, Goodwin EC. 2024. The value of support: STEM intervention programs impact student persistence and belonging. CBE Life Sci Educ 23:ar23. https://doi.org/10.1187/cbe.23-04-0059
61. Hernandez IA, Silverman DM, Destin M. 2021. From deficit to benefit: highlighting lower-SES students' background-specific strengths reinforces their academic persistence. J Exp Soc Psychol 92:104080. https://doi.org/10.1016/j.jesp.2020.104080
62. Yosso * TJ. 2005. Whose culture has capital? A critical race theory discussion of community cultural wealth. Race Ethn Educ 8:69–91. https://doi.org/10.1080/1361332052000341006
63. Intemann K. 2009. Why diversity matters: understanding and applying the diversity component of the national science foundation's broader impacts criterion. Soc Epistemol 23:249–266. https://doi.org/10.1080/02691720903364134
64. Elgin SCR, Bangera G, Decatur SM, Dolan EL, Guertin L, Newstetter WC, San Juan EF, Smith MA, Weaver GC, Wessler SR, Brenner KA, Labov JB. 2016. Insights from a convocation: integrating discovery-based research into the undergraduate curriculum. CBE Life Sci Educ 15:fe2. https://doi.org/10.1187/cbe.16-03-0118
65. Martí-Subirana A, Cook R, Cotter R, Ortíz E, Fraley D, Noravian A, Leonetti C, Franco M, Sweat K. 2022. Implementing course-based undergraduate research experiences (CUREs) in hispanic serving institution (HSI) community colleges
66. Meyer R, Sohani M, Alvares SM, Hunt K, Sciabarra C, Gapinski JG. 2023. Cross-disciplinary CURE program increases educational aspirations in a large community college. CBE Life Sci Educ 22:ar21. https://doi.org/10.1187/cbe.21-09-0258

67. Rosas Alquicira EF, Guertin L, Tvelia S, Berquist PJ, Cole MW. 2022. Undergraduate research at community colleges: a pathway to achieve student, faculty, and institutional success. N Drctns Comm Coll 2022:63–75. https://doi.org/10.1002/cc.20524
68. Sandrin S, Nishimura J, Sexton M, Barbosa S, Marshall P, Chapman A, McCarthy N, Tuohy J. 2023. "I thought it was a little risky": transfer barriers for students with scholarship support. Comm Coll J Res Pract 0:1–18. https://doi.org/10.1080/10668926.2023.2256249
69. Chamely-Wiik D, Frazier E, Meeroff D, Merritt J, Johnson J, Kwochka WR, Morrison-Shetlar AI, Aldarondo-Jeffries M, Schneider KR. 2021. Undergraduate research communities for transfer students: a retention model based on factors that most influence student success. J Scholarship Teach Learn 21. https://doi.org/10.14434/josotl.v21i1.30273
70. Gamage K, McCall J, Daigle H, Miller C. 2022. Supporting STEM transfer students through cross-institutional undergraduate research experiences. J Geosci Educ 70:339–353. https://doi.org/10.1080/10899995.2021.2005510
71. Zuckerman AL, Lo SM, Juavinett AL. 2024. Mentorship for transfer student success in STEM research: mentor approaches and reflections. CBE Life Sci Educ 23:ar27. https://doi.org/10.1187/cbe.23-08-0156