A Call to Assess the Impacts of Course-Based Undergraduate Research Experiences for Career and Technical Education, Allied Health, and Underrepresented Students at Community Colleges

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ABSTRACT

Course-based undergraduate research experiences (CUREs) have the potential to impact student success and reduce barriers for students to participate in undergraduate research. Literature review has revealed that, while CUREs are being implemented at both community colleges (CCs) and bachelor's degree–granting institutions, there are limited published studies on the differential impacts CUREs may have on CC students in allied health programs, career and technical education, and nursing pathways (termed "workforce" in this essay). This essay summarizes proposed outcomes of CURE instruction and explores possible reasons for limited reporting on outcomes for CC and workforce students. It also provides recommendations to guide action and effect change regarding CURE implementation and assessment at CCs. This essay is a call to action to expand the science, technology, engineering, and mathematics career development pathway to include workforce students, implement CUREs designed for workforce students, and assess the differential impacts CUREs may have on workforce student populations at CCs.

INTRODUCTION AND BACKGROUND

Community colleges (CCs) enroll diverse student populations and play an integral role in training the science, technology, engineering, and mathematics (STEM) workforce. With increased calls to use student-centric practices, such as experiential learning and undergraduate research, it is critical to assess CC student outcomes to appropriately evaluate and improve STEM curricula. CC students not only transfer to bachelor's degree–granting institutions, but they also train to enter the STEM or healthcare workforces. As biology educators, we are interested in exploring the benefits of course-based undergraduate research experiences (CUREs) for CC workforce students and populations underrepresented in STEM. For this essay, the term "underrepresented" includes populations historically underrepresented in STEM, such as Black, Hispanic, Native American, and Asian Pacific Islander individuals, as well as students who fall within lower-economic brackets or identify as first generation. First, we will delineate the diverse student populations served by CCs and discuss the important role of CCs in training the STEM workforce. Next, we will discuss gaps in the literature regarding the potential benefits that CUREs may have on workforce and historically underrepresented students at CCs. Finally, we will identify possible problems and challenges and propose recommendations regarding the implementation and assessment of CUREs specifically for CC workforce students.

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CCs Serve More Diverse Student Populations Than Other Institutional Types

With a national focus on increasing and diversifying the STEM career development pathway, it is important to acknowledge the role of CCs in this effort. With more than 1000 CC institutions in the United States, CCs are as diverse as the populations they serve, which include first-generation students (29%), single parents (15%), students with disabilities (20%), and military-connected veterans (4%; Dimino, 2019; American Association of Community Colleges [AACC], 2022). CCs also enroll a higher percentage (46%) of students that fall within the lowest-income quartile (AACC, 2020).

CCs serve as a primary point of entry to higher education for historically underrepresented students (AACC, 2022; National Center for Education Statistics [NCES], 2022; National Science Foundation [NSF], 2022). While other institutions also serve underrepresented populations of students, CCs often serve a higher proportion of these student populations (Schinske *et al.*, 2017). A significant proportion of Hispanic and Black students begin their initial course work at CCs (Ashcroft *et al.*, 2021). Specifically, CCs enroll 53% of Native American, 50% of Hispanic, 40% of Black, and 36% of Asian/Pacific Islander undergraduate students in the United States (AACC, 2022). Nearly half of all students earning science and engineering bachelor's degrees complete some of their course work at CCs (NSF, 2020), and students from historically underrepresented groups, such as Latino or Black students, are more likely than their white counterparts to have earned an associate's degree from a CC (Foley *et al.*, 2021). In contrast, students from underrepresented groups account for just 21% of STEM bachelor's degrees (National Science Board [NSB], 2018; Weatherton and Schussler, 2021). Due to the fact that they enroll such a large proportion of students historically underrepresented in STEM fields, CCs have the potential to expand and diversify the STEM workforce (Berkner *et al.*, 2008).

CCs Play a Key Role in Training the STEM Workforce

There is increasing interest among government and industry stakeholders regarding the role that CCs play in STEM education pathways (Olson and Labov, 2012; Lundy-Wagner *et al.*, 2014; Lundy-Wagner and Chan, 2016; NCES, 2022). CCs have a dual mission of providing a transfer pathway to bachelor's degree–granting institutions and training and preparing students for the workforce. Between 2004 and 2009, the Center for Analysis of Postsecondary Education and Employment (CAPSEE) reported that, while 17% of the student population was enrolled in a traditional STEM field, 9% of students were enrolled in allied health STEM fields, and an additional 8% in technology or technician STEM programs such as automotive technology (Lundy-Wagner and Chan, 2016). It is worthwhile to note that approximately 55% of STEM workers do not have a bachelor's degree, with 19% of those working in healthcare (Okrent and Burke, 2021). However, as acknowledged by organizations such as the National Academies of Sciences, Engineering, and Medicine (NASEM, 2017) and the NSB (2019), the lack of a bachelor's degree does not diminish the role that workers with STEM-related training play in the overall STEM labor force.

Where are these STEM workers being trained? From 2018 to 2019, CCs awarded 1 million associate's degrees, with 182,600 (18.3%) of those in the health professions and related programs (NCES, 2022). In fact, CCs educate the majority of career and technical education (CTE), nursing, and allied health students, which includes professions that promote wellness and disease prevention and support healthcare through administration and management (Skillman *et al.*, 2012; Association of Schools Advancing Health Professions 2015). For this essay, these three populations are grouped and discussed as a single unit, "workforce students." Like CTE programs, both nursing and allied health programs are heavily based on applied sciences and industry-level credentialing.

If we are committed to increasing STEM diversity in higher education and STEM fields, we need to acknowledge the role that CCs play in recruiting, training, and preparing these students for transfer to bachelor's degree–granting institutions or STEM-related occupational fields. We must invest in initiatives that attempt to study these students earlier in their academic pathways where they are enrolled in larger proportions. This may help us determine why the average rate of transfer among CC students is 8–20% (Zuckerman and Lo, 2021). These data are needed to identify potential policies, practices, and interventions that can help these students persist and succeed in STEM career pathways.

STEM Workforce and STEM Degree Students Share Common Early Academic Course Work

STEM courses at CCs serve as foundational classes required for a variety of academic pathways. Not only are these STEM courses part of the transfer pathway to bachelor's degree–granting institutions, but they are also part of the applied sciences pathways that lead directly to the workforce. Many workforce students, particularly those from allied health and nursing, complete prerequisite STEM course work before branching into their prospective pathways. For example, nursing students may be required to complete general biology followed by two semesters of anatomy and physiology and one semester of microbiology (Phoenix College, 2019) for their programs. This means that workforce students are often part of the STEM training pathway during the early stages of their course work.

Access to Undergraduate Research Experiences (UREs) Is Important for Both STEM Degree and Workforce Students at CCs

STEM training pathways should not only help students develop content knowledge, technical skills, and scientific literacy, but should also promote collaboration, communication, and pro-science attitudes. UREs have been reported to lead to many of these outcomes (Lopatto, 2007; Lopatto *et al.*, 2008; Drew and Triplett, 2008; Shaffer *et al.*, 2010; Jordan *et al.*, 2014). For this reason, Swede and Bouklas posited that research opportunities are equally as important for pre-professional healthcare students as they are for students in traditional STEM degree pathways (Swede and Bouklas, 2018). Based on the Health Workforce Strategic Plan, it is important to create learning environments that help healthcare students develop the ability to translate and apply knowledge acquired through scientific research to address emerging public health crises, such as the recent COVID pandemic (U.S. Department of Health and Human Services, 2021).

CUREs Broaden Participation in Undergraduate Research at CCs

CUREs, which fall under the larger umbrella of UREs, have been proposed as one means to increase access to research and its benefits for a larger, more diverse population of students, including those who attend CCs (Bangera and Brownell, 2014; Dvorak and Hernandez-Ruiz, 2019). Integrated into the existing course curriculum, CUREs can help mitigate time and financial constraints that limit CC student participation in research by using scheduled class hours and designated classroom spaces to provide research experiences (Ashcroft *et al.*, 2021). CUREs allow students to work collaboratively and use iterative scientific practices to conduct research that leads to novel discoveries with relevance to the larger scientific community (Auchincloss *et al.*, 2014). CUREs also provide students with opportunities for iteration and troubleshooting (Auchincloss *et al.*, 2014), which may contribute to the development of workforce-relevant skills (Ashcroft *et al.*, 2020), such as critical thinking and problem solving (Balke *et al.*, 2021).

Over the past decade, CUREs have expanded at CCs, due in part to initiatives such as the Course-based Undergraduate Research Experience network (CUREnet) and the Community College Undergraduate Research Initiative (CCURI), which support development, mentoring, and funding of UREs (Hewlett, 2018, 2021). The momentum CCs are gaining in broadening research experiences for their students through UREs and CUREs was showcased in the Spring 2021 issue of *Scholarship and Practice of Undergraduate Research* (Hewlett, 2021). The articles in this issue discussed how the proposed impacts of UREs, including CUREs, on student success make these high-impact practices worthwhile at CC institutions (Kolokithas, 2021). Despite increased implementation, CUREs at CCs appear understudied and underreported in the literature.

IDENTIFYING GAPS IN THE LITERATURE REGARDING CURES FOR CC AND WORKFORCE STUDENTS

It is critical to first understand the extent to which CC students are included in studies of CUREs to determine whether CC students experience CURE instruction differently than students at other institutional types. Thus, we carried out a review of the published research on CUREs to identify the extent to which CC students were included as participants. We conducted our search through several stages and reviewed the methods sections of each paper to determine whether CC students were part of the participant sample and, if so, whether information about CC students was disaggregated. In the following sections, we share an overview of our findings.

Problem 1. Research about CURE Implementation with CC and Workforce Students Is Limited

As CC faculty conducting biology education research (BER), we were interested in identifying the extent to which URE and CURE implementation has been reported for CC students. For this essay, we surveyed the available literature relative to CUREs in CCs and for subpopulations such as allied health and CTE students. We conducted a review of the literature using Summon. This utility searches the Ex Libris Central Discovery Index, which aggregates search results across separately subscribed content including these five databases: Education Resources Information Center (ERIC), Education Full-Text, Academic Search Premier (EBSCO), Gale Academic OneFile, and ScienceDirect. When we entered the search terms "course-based undergraduate research experiences" and "allied health," Summon produced 32 publications that included allied health students or topics in research. However, most of these studies were conducted at bachelor's degree–granting institutions. For example, one study conducted at Illinois State University infused a CURE into an applied science course for medical laboratory students (Johnson *et al.*, 2021), while another study at Long Island University described research experiences that were integrated into courses that serve both science majors and pre–professional healthcare students (Swede and Bouklas, 2018).

When we included the term "community colleges," the search results were further narrowed to just eight articles, with only two articles addressing CC research with allied health specifically. One example, reported by Queensborough Community College–CUNY, involved an antibiotic-resistance research project that was integrated into a microbiology course required for allied health students (Tawde and Williams, 2020). Another article, this one about Delaware Technical Community College, described how course-based and mentored research experiences were integrated into microbiology and biotechnology courses (Balke *et al.*, 2021). Notably, no articles were identified when searching for "course-based undergraduate research experiences" and "community colleges" and "career and technical education." The lack of published studies focusing on participation of CC workforce students in CUREs identifies an important gap in the literature. While we acknowledge there are likely CCs implementing CUREs with workforce students, there is currently limited published research available regarding this work.

Problem 2. CURE Outcomes Are Not Well Studied or Reported for CC and Workforce Students

In the next section, we will summarize what has been learned about the benefits of UREs, discuss how CUREs may have similar benefits, and identify gaps in the literature regarding the populations of students for which these outcomes have been reported.

The Reported Benefits of URES. UREs for STEM majors have been reported to have a variety of beneficial outcomes. These include critical thinking (Ishiyama, 2002; Seymour *et al.*, 2004; Hunter *et al.*, 2007), understanding of research processes (Lopatto, 2003), and improved communication skills (Kardash, 2000; Seymour *et al.*, 2004; Hunter *et al.*, 2007). Affective gains in students' attitudes and self-confidence have also been observed after participation in research (Thiry and Laursen, 2011). Other reported benefits of UREs include increased self-efficacy (Thiry and Laursen, 2011; Adedokun *et al.*, 2014) and perseverance when faced with challenges (Lopatto, 2007).

As a high-impact practice, UREs can be particularly beneficial for underrepresented student populations (Villarejo *et al.*, 2008; Hurtado *et al.*, 2010; Espinosa, 2011; Hernandez *et al.*, 2013; Estrada *et al.*, 2016, 2018). Estrada *et al.* (2018) reported that research experiences for demographic groups traditionally underrepresented in STEM can lead to increased retention in STEM career pathways. Carpi *et al.* (2017) reported that UREs can lead to increased self-efficacy and motivation to pursue

STEM careers among Black, Indigenous, and people of color. UREs have also been reported to lead to increased graduation rates among populations underrepresented in STEM (Nagda *et al.*, 1998; Krim *et al.*, 2019). While the majority of URE studies in the literature were conducted at colleges and universities, Damas *et al.* (2020) and Nerio *et al.* (2019) report that URES at CCs have the potential to increase graduation rates and transfer from CCs into bachelor's degree–granting STEM programs (Nerio *et al.*, 2019; Damas *et al.*, 2020). However, it is important to note that data regarding transfer of underrepresented students from CCs to STEM programs at bachelor's degree–granting institutions can be challenging to track (Ashcroft *et al.*, 2020) and do not always take into account that many workforce students have an intent to enter occupational programs rather than seek a bachelor's degree.

Lack of Data Regarding the Benefits of CUREs for CC and Workforce Students. While the impacts of UREs have been more widely studied and reported, the impact of CUREs, particularly on CC and workforce students, is less established in the literature. CUREs have been proposed to have many of the same positive outcomes for students as those described for UREs (Shaffer *et al.*, 2010; Mader *et al.*, 2017; Hanauer *et al.*, 2022; Lopatto *et al.*, 2022). Based on a review of the URE literature, the proposed outcomes of CUREs (Corwin *et al.*, 2015a) include increased content knowledge, improved analytical and technical skills, increased project ownership (Shaffer *et al.*, 2010; Alkaher and Dolan, 2014; Hanauer and Dolan, 2014), science identity (Hanauer *et al.*, 2012; Alkaher and Dolan, 2014), and sense of belonging to the scientific community (Russell *et al.*, 2007; Shaffer *et al.*, 2010; Jordan *et al.*, 2014; Corwin *et al.*, 2015b; Hanauer *et al.*, 2016). However, it is important to note that many of these outcomes are hypothesized based upon findings from other URE studies and have not been comprehensively assessed for CUREs. This is an important gap in the CURE assessment literature that warrants further investigation.

Most reporting on CURE assessments in the literature has focused primarily on large-scale programs such as the Science Education Alliance Phage Hunters Advancing Genomics and Evolutionary Science (SEA-PHAGES; Jordan *et al.*, 2014; Mader *et al.*, 2017; Hanauer *et al.*, 2022), the Genomics Education Partnership (GEP; Lopatto *et al.*, 2008, 2022; Shaffer *et al.*, 2010; Mader *et al.*, 2017), and other phage genomics courses (Hatfull *et al.*, 2006; Caruso *et al.*, 2009; Harrison *et al.*, 2011). For example, CC students who participated in the SEA-PHAGES CURE at Del-Mar College reported gains in scientific literacy, increased understanding of how scientists think, and readiness to participate in future research (Overath *et al.*, 2016). CUREs have also been reported to lead to increased persistence and retention in STEM (Rodenbusch *et al.*, 2016; Hanauer *et al.*, 2017).

While articles describing proposed benefits of CUREs for non-STEM majors, such as improving scientific literacy skills, evidence-based decision-making skills, and pro-science attitudes toward research and scientists, were found in the literature (Caruso *et al.*, 2009; Ballen *et al.*, 2017), we were not able to identify specific examples in the literature of the impacts CUREs have on CC workforce students. It is important to study the impact of CURES on workforce students because as argued by Osborne *et al.* (2003), skills essential for traditional STEM students training to become researchers or engineers can also be beneficial for students training to enter the workforce. According to Hirschy *et al.* (2011), it is essential that we understand how CTE students differ from STEM academic degree pathway students to develop strategies to increase retention and learning outcomes for this population.

Need for Mixed-Methods Analysis of CURE Impacts on CC and Workforce Students. Several CURE assessments have been used, primarily with students at bachelor's degree–granting institutions, to measure learning outcomes related to the process of science, scientific literacy, collaboration, sense of belonging, self-efficacy, motivation to learn science, and pro-science attitudes (summarized by Corwin *et al.*, 2015a; Shortlidge and Brownell, 2016; Krim *et al.*, 2019; and annotated by Crowe and Brakke, 2020). However, as discussed by Irby *et al.* (2018) and Linn *et al.* (2015), while many anticipated learning outcomes have been reported in the literature, there is a lack of robust, mixed-methods studies that validate student-reported gains with direct measures of content learning gains and institutional evidence of persistence in STEM fields. Linn *et al.* (2015) highlight the need for assessments that use student work to document student progress and evaluate specific CURE outcomes for populations of students with distinct backgrounds and career interests. While it is possible that CUREs are an effective way to foster positive outcomes for workforce students, data collection and reporting appear to be lacking for this population. These gaps in the published data warrant the need for increased data collection and analysis to identify the differential impact CUREs may have on CC workforce students.

Assessing the impacts of CUREs on CC and workforce students is important not only for the improvement of STEM curriculum, but also for the diversification of STEM career pathways. As the reader may recall, after completing introductory STEM course work, STEM workforce students take different academic paths and therefore, may have different goals or definitions of success. If we want to measure the impact of CUREs on workforce students, we need to consider the differential goals of these students. In the following section, we explore common definitions of success and missions of CCs.

Problem 3. Baccalaureate-Centered Definitions of Success Do Not Account for the Diverse Goals of CC Workforce Students

As discussed earlier, CCs have a dual mission to not only prepare students for transfer, but also to train the workforce. CCs serve at least 47% of underrepresented and 62% of allied health students (Skillman *et al.*, 2012; AACC, 2022). Because CCs play an important role in transfer preparation and workforce training for these students, defining and tracking student success is critical for improvement in the higher education system (Dimino, 2019). Dimino points out that traditional outcome metrics, such as graduation and transfer, do not fully account for the diversity of CC students and their prospective goals, the variety of pathways offered, or the missions of CCs (2019). In addition, the federal government does not distinguish between CC and bachelor's degree–granting institutions when reporting student outcomes (Dimino, 2019). Therefore, federal reporting on CC success has created uncertainties about institutional and student-level performance, underscoring the need to expand availability of higher education data and open dialogue regarding the ways we think about success for all CC students (Dimino, 2019).

How student success is defined depends largely on the context and who is being asked (Thompson and Jensen-Ryan, 2018). Higher education literature broadly defines student success as the degree to which individuals achieve their educational goals, which may not be as simple as degree completion (Hirschy *et al.*, 2011). As biology educators, we reviewed the literature to see how BER defines student success and found that, while it is not explicitly defined, it is often based on metrics established for students in STEM programs at bachelor's degree–granting institutions (Weatherton and Schussler, 2021). Institutions often measure success in terms of quantitative academic outcomes such as grade point average (GPA), exam scores, and transfer rates (Weatherton and Schussler, 2021). They less frequently consider social, cultural, or personal student impacts such as sense of belonging, identity, and self-efficacy (Weatherton and Schussler, 2021). Focusing on academic standards has led to "best practices" in higher education based on the majority versus underrepresented populations (Yao, 2015; Muñoz and Maldonado, 2012; Burt *et al.*, 2019). For example, if success is defined by quantitative measures such as course grades and GPA, then institutional resources will be predominantly allocated to capacities and resources that support academic outcomes of success such as tutoring and learning centers, rather than supporting career-based outcomes of success such as work-based experience initiatives and career centers (Weatherton and Schussler, 2021).

Research on CC institutions often focuses on how CCs function as a career development pathway for transfer preparation and STEM degree completion (Lundy-Wagner and Chan, 2016). Using data from the Virginia Community College System, Lundy-Wagner and Chan (2016) indicate that research on CC institutions largely ignores certificates or CC degrees geared toward the workforce pathways sought by many CC students. While it is easier to use transfer of STEM students to bachelor's degree–granting institutions as a measure of success, CC students in applied educational or training paths can make progress in a variety of ways, including taking courses in different order, at different times. This nonlinear or nonsequential progress is likely to have been overlooked, given the current study methods and the types of outcomes that have been prioritized in research on CUREs. CTE students are more likely to be scanning the labor market frequently and adjusting their educational goals to accommodate their chosen career by either leaving without completing a degree (if their chosen field does not place emphasis on the credential) or by increasing their educational goals if their chosen career requires more education than previously thought (Stuart *et al.*, 2014).

While Hispanic and underrepresented students are as likely as white students to major in STEM, their success (as defined by completion rates) remains lower (Krogstad and Lopez, 2014; Ero-Tolliver, 2019). When baccalaureate completion is the primary or sole metric of success, it may appear that CCs have a negative impact on students pursuing transfer to a bachelor's degree–granting institution, because research shows CC students are less likely to earn a STEM bachelor's degree (Lundy-Wagner and Chan, 2016). Weatherton and Schussler assert that this can lead to the false assumptions that higher attrition rates and lower course grades are due to deficiencies among underrepresented students (Weatherton and Schussler, 2021). However, lower completion rates may also be concomitant with economic factors, such as the cost of college and graduate programs, lack of STEM jobs, underpaid research jobs, and the age of the transfer student. Weatherton and Schussler discuss how these narratives place blame for disproportionate outcomes (i.e., wage gaps, lower academic persistence, and achievement) on underrepresented students by claiming they are deficient in some way without recognizing that the standards of academic success are biased toward the majority (Weatherton and Schussler, 2021). This can affect students' sense of belonging (Hurtado and Carter, 1997; Hurtado *et al.*, 2015; Tibbetts *et al.*, 2016), impact their retention in STEM fields, and have lasting impacts when it comes to the success of diverse populations (Weatherton and Schussler, 2021).

CHALLENGES AND RECOMMENDATIONS

Each of the problems listed persists as a result of complex, but not intractable challenges. These challenges are explored in the following sections, accompanied by recommendations for action. We hope these recommendations spur increased dialogue among faculty, administrators, workforce and historically underrepresented students, and leaders from STEM initiatives to collaboratively support CURE implementation and assessment for all students enrolling in STEM courses at CCs.

Overcoming Barriers to and Lack of Data Regarding CURE Implementation at CCs (Problem 1)

CC faculty participation in undergraduate research likely varies greatly from school to school, depending on programs offered, faculty mentoring, student body composition, and access to professional development funds. The extent to which CC faculty across the United States are encouraged or supported in undergraduate research initiatives is not well reported in the literature. Limited implementation of CUREs by CC faculty may be due more to the lack of awareness regarding the benefits of CUREs versus lack of interest in providing these experiences for their students. This emphasizes the need for widespread equitable outreach, training, and support for CURE development at CCs.

Even if interest is present, CC faculty face a variety of challenges regarding the implementation of research experiences (Pierszalowski *et al.*, 2021). CC faculty are primarily occupied with teaching, but are also involved in college-wide initiatives, committees, and supervisory assignments, leaving less time for professional development, networking, and other student-driven advocacy efforts. They often lack the time or resources needed to develop research experiences and may feel unsupported or even marginalized in the science research community (Ashcroft *et al.*, 2021). Access to laboratory equipment and supplies, financial resources, and administrative support are also required for successful development, implementation, and assessment of research programs, which can hinder CC faculty from engaging in or sustaining these initiatives (Ashcroft *et al.*, 2020; Pierszalowski *et al.*, 2021).

Similarly, CC students face myriad of external challenges that may interfere with their ability to participate in independent research or other extracurricular activities (Ashcroft *et al.*, 2021). Such hindrances can include time constraints, difficulty balancing part-time or full-time work with school, financial obligations, caregiving requirements, lack of reliable transportation, and challenging life circumstances (Dimino, 2019; Ashcroft *et al.*, 2021; Pierszalowski *et al.*, 2021; Stofer *et al.*, 2021). Underrepresented students may not feel there is a place for them in STEM (Hurtado *et al.*, 2015) and may lack awareness of STEM undergraduate research opportunities or career pathways. Uncertainty about the true reasons for underparticipation is compounded when less than 4% of published BER is from CC authors (Schinske *et al.*, 2017). In the following sections, we recommend ways to mitigate hurdles to participation in research faced by CC faculty and students

Recommendation 1a. Increase Support for CURE Development and Implementation at CCs. There is a decreasing trend in CC enrollment nationwide (Conley and Massa, 2022). Increasing student persistence and success is an impetus for CCs to promote CUREs as a high-impact practice and provide professional learning initiatives to support implementation by CC faculty. However, curricular changes require professional development, infrastructure, and institutional support for CC faculty. This includes time for CURE curriculum development, space allocation, project funding, and training for faculty and support staff (Wolkow *et al.*, 2014). One recommended strategy is to provide newly hired CC faculty with mentoring and training on how to effectively develop and implement CUREs into the curriculum. Many CCs have teaching and learning centers and a variety of professional development opportunities that could be used to promote CUREs as a high-impact practice, foster community building, assist with curricular development, and provide mentoring.

It would also be beneficial to support more regional and national conferences designed by and for CCs to foster collaboration and increase training in the development and implementation of CUREs. The NSF-funded conference “Improving STEM Education at HSI Community Colleges by Introducing High Impact Course-based Undergraduate Research Experiences (CUREs)” aims to provide models for CURE design, implementation, and assessment with the intent of promoting a culturally relevant and equitable approach to STEM teaching (https://nsf.gov/awardsearch/showAward?AWD_ID=2211811&HistoricalAwards). Ideally, teams consisting of both CC faculty and administrators should participate in these events to better understand the impacts CUREs can have on student learning outcomes and how this work can support the dual mission of CCs.

Institutional and administrative support can also help address challenges faculty may face when implementing CUREs (Ero-Tolliver, 2019). Aligning CURE development with institutional policies and initiatives and establishing partnerships with networks like CUREnet can help alleviate administrative concerns and other hurdles. For example, Ero-Tolliver discussed how partnering with CUREnet and campus administrators helped launch faculty development opportunities for addressing barriers and subsequently creating CUREs at Hampton University (Ero-Tolliver, 2019). More partnerships with bachelor’s degree–granting institutions and dual-enrollment programs could also help alleviate these strains (Ashcroft *et al.*, 2021; Hewlett, 2021).

CCs are primarily teaching institutions rather than research institutions. As such, CCs often need to seek external funding sources to support this work. Programs like the NSF Improving Undergraduate STEM Education: Hispanic Serving Institutions program have provided support for CURE training and development at CC institutions. For example, the NSF-funded STEM-CURE project in the Maricopa County Community College District (https://sites.google.com/phoenixcollege.edu/mcccdstemcure/home) provides training, mentoring, and resources to help CC faculty develop, implement, and assess CUREs in courses for STEM majors, non-STEM majors, and workforce students across its 10-college district. The STEM-CURE program partners with local universities, government agencies, and industry to provide students with access to research opportunities and resources not traditionally available at CCs. Although NSF continues to fund programs that support development of CUREs as a high-impact practice for STEM students, one recommendation is that both the NSF and the National Institutes of Health invest in CUREs for health-related workforce students and the CC faculty who train them. We recommend expanding existing CURE studies to include more CC and workforce students and, if needed, create customized CUREs for CC workforce students.

Recommendation 1b. Continue to Expand Communities of Practice. The CCURI has played a key role in the expansion of UREs/CUREs at CCs through its network of 124 partner CCs (Hewlett, 2021). This expansion has been supported by the creation of regional and national collaborations and professional development opportunities for faculty, including, but not limited to, workshops and conferences. Since 2012, CUREnet has also provided faculty with training and resources to aid in the development, teaching, and assessment of CUREs (https://serc.carleton.edu/curenet/index.html). Other initiatives, such as Mentoring the Integration of Research Into the Classroom (MIRIC), focus on sustaining mentor–mentee relationships and supporting the specific needs of mentees (Wolyniak *et al.*, 2020). There is a need for more initiatives like MIRIC, which not only provides substantial training on the implementation of CUREs, but also focuses on sustainability and fostering change in life science courses taught in the United States (Moris, 2021). Communities of practice can also be used to transform STEM curriculum using student-centric practices (Tomkin *et al.*, 2019; Hurley *et al.*, 2021) and leveraged to develop professional learning communities to foster student experiences in STEM (Glaze-Crampes, 2020). Communities of practice that involve both faculty at CC and bachelor’s degree–granting institutions have the potential to foster mentoring networks that can support students during the critical transfer process (Ashcroft *et al.*, 2021).

Several large-scale CUREs have been implemented at a variety of institutional types in the United States and around the globe. The GEP is a national collaboration between the Department of Biology and Genome Center of Washington University–St. Louis and more than 200 institutions of higher education across the United States conducting CUREs on genomics and bioinformatics (Lopatto *et al.*, 2008). Funded by the Howard Hughes Medical Institute, the SEA-PHAGES CURE has trained both STEM and non-STEM majors from more than 160 institutions, which range from associate’s degree–awarding institutions to research institutions (Hanauer *et al.*, 2022). As a global CURE, the Tiny Earth network engages students from 30 countries in antibiotic discovery research (https://tinyearth.wisc.edu). The Tiny Earth network is an instructor-led community of practice that makes research more accessible to students at a variety of institutional types, including minority-serving institutions and CCs. Of the institutions that participate in Tiny Earth, 56% are bachelor's degree–granting institutions; 11% are research institutions; 14% are CCs; and 19% include other institutions, such as high schools (Handelsman *et al.*, 2022; Miller *et al.*, 2022).

The Tiny Earth network (Hurley *et al.*, 2021) and SEA-PHAGES (Hanauer *et al.*, 2022) serve as models for how CUREs can be implemented at a variety of institutional types through the use of robust training and mentoring networks. For example, the Tiny Earth network hosts annual workshops, provides mentoring, assists with sample analysis, collates data into a global database, and offers summer symposia where students can share their findings. A major strength of SEA-PHAGES is its mentor-based approach, which supports training for new cohorts and matches participants by institutional type. Faculty and students can use message boards to seek advice from the wider network. SEA-PHAGES students actively participate in a yearly conference, gaining experience and networking time with faculty and other students from all participating institutions. Faculty can also participate in faculty-centered conferences and professional development to serve as mentors and participate in annual training. Successful model CUREs, such as Tiny Earth and SEA-PHAGES, can provide an existing support framework to aid in the implementation and assessment of CUREs at CCs.

In addition to increasing CC participation in model CUREs, expanding programs such as the MIRIC initiative and CCURI could help provide a robust training and mentoring network for CC faculty interested in developing CUREs. While some information regarding the number of CC participants in national or global CUREs is available, it is not certain how many CC faculty are using self-developed CUREs or who are implementing national CUREs without being part of the recognized cohort. It would be beneficial to know how many CC faculty are implementing CUREs, and why others elect not to participate. Large networks such as CCURI and CUREnet could help achieve this through survey dissemination. These networks could also be used to foster outreach and training initiatives, which in turn could lead to the expansion of CURE communities of practice.

Instruments to Assess CURE Impacts Have Not Been Widely Tested with or Designed for CC Workforce Students (Problem 2)

Assessment instruments that have been used to study and report the impacts of CUREs and other UREs appear to originate with and primarily include students from bachelor's degree–granting institutions (Shortlidge and Brownell, 2016). Commonly used instruments to assess UREs and CUREs include the Undergraduate Research Student Self-Assessment survey (Hunter *et al.*, 2007; Weston and Laursen, 2015), the Persistence in the Sciences (PITS) survey (Hanauer *et al.*, 2016, p. 20), the Classroom Undergraduate Research Experience (CURE) survey (Lopatto, 2008), and the Laboratory Course Assessment Survey (LCAS; Corwin *et al.*, 2015b). The majority of these instruments were originally designed for use with students at bachelor's degree–granting institutions. This means they may not reflect the diverse backgrounds, credential goals, and voices of workforce student populations at CCs. For example, benchmark data for the CURE survey included just 7.1% Black or African-American and 9.9% Hispanic/Latino students, while the majority of student participants (59.5%) identified as Caucasian/White (Lopatto, 2008). In contrast, CCs enroll a larger proportion of students who identify as Hispanic/Latino (28%) or Black (13%; AACC, 2022). Although the PITS survey (Hanauer *et al.*, 2016) was originally used with an undergraduate student population that identified as 52% Caucasian/White and only 2% Black or African American, and just 1% Hispanic or Latino, this survey is now used at a variety of institutional types ranging from CCs to bachelor's degree–granting institutions (Hanauer *et al.*, 2017). Hanauer *et al.* (2022) recently published a study using data collected from nine different CCs. In contrast to the original population studied, the most recent SEA-PHAGES CC study consisted of 44% White/Asian students and 56% of persons from historically STEM-excluded ethnic and racialized groups, who include Black (15%), Latinx (45%), Native American (1%), and Hawaiian and Pacific Islander individuals (1%; Hanauer *et al.*, 2022).

The populations of students included in CURE studies have traditionally not been well described in the literature (Dolan, 2016; Hanauer *et al.*, 2022). While national databases for accessing higher education statistics for CCs (AACC, NSF, NCES, and CAPSEE) do exist, it is difficult to find or access stratified data collected from CURE studies at CCs. In their review of UREs, CUREs, and teacher research experiences, Krim *et al.* (2019) reported that, while prior studies have indicated the importance of studying the impact of UREs/CUREs on underrepresented students (Nagda *et al.*, 1998; Davis, 1999; Sadler *et al.*, 2010), 64% of the studies they reviewed did not include or mention the involvement of underrepresented students (Krim *et al.*, 2019). Moreover, they found that the majority of studies about the impacts of CUREs and UREs failed to include demographic data showing the percentage of students from underrepresented populations (Krim *et al.*, 2019). Without access to student success data for CC students in CUREs, we cannot make improvements in real time or better inform our STEM curricula.

Linn *et al.* (2015) emphasize how analyzing the benefits for underrepresented subgroups could help researchers better identify and address the unique needs of these students.

In most cases, the dual mission, diverse student populations, and multitude of career pathway options at CCs have not been taken into consideration when designing assessments that measure CURE impacts on CC student outcomes (Dimino, 2019). How can we understand the impact of CUREs on CC and workforce students if they are not being included in the studies or differentiated in the data? If CCs serve the largest proportion of underrepresented students, but CC data are largely missing from the CURE literature, then only a small proportion of those students and their experiences are being reported.

Furthermore, the assumption that CUREs have similar benefits for both CC STEM majors and workforce students has not yet been widely tested or, at the very least, reported in the literature. The instruments designed to assess the impact of CUREs on STEM majors at bachelor's degree–granting institutions may not be capturing the impact CUREs have on job-related readiness skills for CC workforce students. For example, nurses and allied health professionals serve as important liaisons between the scientific research community and the larger population. As healthcare providers, they are directly involved in patient education. Therefore, it is imperative that they be trained in the critical evaluation and dissemination of scientific information related to disease prevention and treatment. If CUREs have been demonstrated to promote pro-science attitudes and job-related readiness skills such as critical thinking, collaboration, and problem solving, then the inclusion and assessment of STEM-related workforce students in CUREs should be promoted. Without inclusion of the diverse student populations CCs serve, it will be difficult to determine whether or in what ways CC workforce and underrepresented students benefit from participating in CUREs.

Recommendation 2a. Increase Data Collection and Accessibility. We recommend that demographic data for future studies should be made available and include first-generation status, ethnicity, gender identity, age, and academic pathway (STEM major vs. non-STEM vs. workforce). To foster an open science approach in undergraduate STEM education, studies could disaggregate by institutional type or scholars could include raw data that can be mined or analyzed by other researchers, enabling better meta-analysis in the future. It would also be beneficial for education researchers to report the extent to which existing instruments have been used to assess the impact of CUREs on students from CCs. While some instruments report including CC students in their data, they rarely provide specific demographics or indicate the varying programs of study for CC students. Collecting and reporting these data at a larger scale will be useful as educators determine if, and in what ways, CUREs are beneficial to different populations of CC students, including those who identify as STEM majors, non-STEM majors, or workforce students.

CCs with limited institutional research support may find power in collaborating with the science education community through groups like the Community College Biology Instructor Network to Support Inquiry into Teaching and Education Scholarship (Chen Musgrove *et al.*, 2022) and the Society for the Advancement of Biology Education Research. By inviting researchers who design, pilot, and collect validity evidence to assist in analyses, we can: 1) use the same instruments for generating meaningful comparison data; 2) help stratify data collection; and 3) carry out validation work with subpopulations of CC students. A mixed-methods approach with both quantitative and qualitative assessments should be used to provide a more comprehensive picture of the impact of CUREs on CC students.

Barriers for CC faculty to publish and share findings with the greater educational research community should be reduced when possible. It should not be cost prohibitive to access articles, publish, or attend relevant conferences, particularly for CC faculty and students. It is worth noting that CCs perform genuine research but often encounter hefty publication fees, which disincentivizes the dissemination of findings to the larger education research community. While waiver applications and limited duration grant funds do exist to help CC faculty, systemic reduction of fees may provide incentives for CC faculty to further engage and participate in education research.

Recommendation 2b. Use a Mixed-Methods Approach to Study the Impact of CUREs on CC and Workforce Students. As outcomes may vary for CUREs designed for STEM majors versus non-STEM majors or workforce students, survey instruments currently used to assess the impact of CUREs may require adaptation, development, or expansion. We propose that model networks and national initiatives should be harnessed to partner with CCs to conduct meaningful CURE assessments. This could include working together to develop instruments designed for use with the diverse populations of students predominantly served by CCs (underrepresented, nontraditional, and workforce). Regardless, we first need to examine current instruments and their usefulness for differentiating the impacts of CUREs at CCs. To increase data collection on the impact of CUREs, CC faculty should consider working with science education researchers who have already invested in the creation and collection of validity evidence of CURE instruments. Specifically, it would be helpful if networks like CUREnet, CCURI, Tiny Earth, and SEA-PHAGES could assist CC faculty in the collection of data from CC students from underrepresented groups and workforce programs.

It is possible that new instruments may need to be created for and validity evidence collected with CC students to better explore the differential impacts CUREs have on this population of students. Most of what has been published has been assessed using instruments such as the CURE survey (Lopatto, 2008), PITS (Hanauer *et al.*, 2016), and LCAS (Corwin *et al.*, 2015b) surveys. While Likert-scale instruments can show student-reported shifts in attitudes and gains in confidence and self-efficacy, a mixed-methods approach that incorporates not only surveys, but also interviews and focus groups would provide a more comprehensive understanding of how CUREs impact distinct student populations such as CC workforce students.

While we have seen several small-scale case studies based on individual CUREs, large-scale reporting using mixed-method assessments (quantitative and qualitative) appear to be lacking in the literature. We recognize that this process entails a substantial amount of work and expertise (McCoach *et al.*, 2013; Bandalos, 2018). While this could pose a challenge, CC faculty should consider grant funding to support this work or develop collaborations with colleagues who are already doing this work at other associate's or bachelor's degree–granting institutions. We hope that education-focused faculty interested in seeing a shift in attitude toward pro-research initiatives at teaching-oriented CCs will answer this call to action.

Research Culture Is Not Inclusive of CC Workforce Students (Problem 3)

We believe the current definition of a STEM student and STEM occupation is limited in scope, as it does not typically include workforce students as defined in this essay (Gonzalez and Kuenzi, 2014; Oleson *et al.*, 2014a,b). In fact, jobs that require some STEM knowledge are frequently excluded from labor market analyses of STEM occupations, resulting in undervaluing of postsecondary awards (Oleson *et al.*, 2014a,b). There is a need to establish which programs of study constitute STEM in CCs (Oleson *et al.*, 2014a,b; Lundy-Wagner and Chan, 2016).

Without doing so, comparing research on the benefits of CTE, vocational, and occupational credentials is extremely difficult, if not impossible (Lundy-Wagner and Chan, 2016). Oleson *et al.*'s (2014b) investigation of the alignment between goals and priorities of educators and employers revealed the difficulty in defining what constitutes a STEM occupation. The lack of research focus on career-oriented credentials, consensus on who is considered a STEM student (Lundy-Wagner and Chan, 2016; Olson and Labov, 2012), and the definition of what constitutes a STEM occupation are factors that likely contribute to the exclusion of CC workforce students from CUREs. Finding consensus regarding whether CC workforce students should be included in STEM is confounded when the conversation is not being prioritized by the STEM community, including CC faculty and other important stakeholders.

Some STEM faculty may not view conducting research with workforce students as critical to the mission of the CC. Additionally, there is a lack of undergraduate research culture at CCs (Hewlett, 2018), and as such, CCs have not traditionally invested in providing research experiences for their students. This becomes more challenging, because research initiatives at CCs are often faculty driven, not institutionally driven, posing issues related to sustainability and scalability of CUREs within a CC institution. CC faculty and administrators may not fully realize the positive impacts the research process can have on student learning outcomes for STEM majors, nonmajors, and workforce students alike. We recommend broadening the definition of STEM to include CC workforce students.

Recommendation 3a. Expand the Definition of Who Is Considered a STEM Student. It has recently been posited that STEM workforce development is less of a structured pipeline (Gibbs and Marsteller, 2016) and more of a braided river (Batchelor *et al.*, 2021). The braided river model is an ideal analogy for STEM workforce development, as it contains various entry points and changes in pace and direction, as life circumstances and opportunities arise (Batchelor *et al.*, 2021). Historically, the pipeline model has contributed to the exclusion of underrepresented and CC students (Bernard and Cooperdock, 2018) and is not appropriate due to the intricacies of modern career seeking and training. While workforce students are not typically considered part of the STEM fields by NSF (Granovskiy, 2018), they often take foundational classes geared toward traditional STEM students. Only after these foundational classes are taken do workforce students branch into applied course work. Regardless of the training entry point or career path outcome, workforce students ultimately enroll in STEM courses facilitated by STEM faculty. We recommend that CC faculty explore if and how CUREs with this population of students may better prepare them for the workforce. Having a scientifically literate and pro-science workforce arguably benefits everyone. Research experiences that emphasize scientific literacy can help pre–professional healthcare students develop a clearer understanding of how science works and how to critically evaluate scientific findings, as well as see the value of science in society (Feinstein, 2011). As faculty from CCs and bachelor's degree–granting institutions advocate for more research and experiential learning experiences for STEM students, we stress the importance of also providing these opportunities for workforce students.

With a growing number of U.S. states offering bachelor's degrees at CC institutions, it becomes even more pertinent to implement high-impact educational practices, such as CUREs, and collect measures of success for current CC courses and programs. Otherwise, CCs may lack robust baseline data for future comparisons and analysis of measures of student success. This is relevant, as there are at least 24 states allowing CC institutions to award bachelor's degrees (Weissman, 2021), often in niches geared toward the workforce (Povich, 2018). We believe that implementing and assessing the differential impacts of CUREs on workforce students at CCs can ultimately help administrators and faculty innovate, improve upon, and fine-tune assessments respective to our programs and foster success for a greater number of students.

Recommendation 3b. Create Coalitions for Change. Creating a culture of change at the institutional and individual levels is a major undertaking, as research scholars need first to access information about change and change theory (Reinholz *et al.*, 2021). As reviewed by Reinholz *et al.* (2021) applying change theory also requires collaboration across disciplines to establish the appropriate change theories or frameworks that will inform change efforts. To direct a culture of change, we believe it is important to form coalitions among STEM faculty, administrators, staff, and students. Identifying key players who are willing or eager to change and have a shared vision is critical for success. An example coalition is the Accelerate Latinx Representation in STEM Education (ALRISE) alliance. Funded by NSF, ALRISE (HRD-2120021) fosters partnerships and leadership through a common vision to mobilize change for STEM students through the implementation of culturally relevant CUREs and work-based experiences at Hispanic-serving institutions. Attending conferences held by the Factors affecting Learning, Attitudes, and Mindsets in Education network (https://qubeshub.org/community/groups/flamenet/about), or similar, can guide team-building and action plans for STEM faculty. Identifying a change model or framework is especially helpful for creating an action plan for change, and while there may not be one "correct" model or framework to apply, multiple approaches may be necessary or offer the most flexible method for enacting change (Kezar, 2018). Ultimately, coalitions will augment the implementation, assessment, and sustainability of CUREs.

Recommendation 3c. Re-evaluate How Success Is Defined and Measured for CC Workforce Students. Faculty involved with higher education research have been issued a call to action to engage in conversations regarding student success and to expand definitions of success to be inclusive of all students (Weatherton and Schussler, 2021). NASEM identified two categories of success: academic success (improvements in grades, GPA, and course pass rates) and STEM pathway success (enrollment, persistence, retention, and credentialing for postbaccalaureate studies or employment in STEM fields; Gonzalez and Kuenzi, 2014). Instead of using the Integrated Postsecondary Education Data System, which uses traditional metrics of success, the AACC (2022) recommends the use of the Voluntary Framework of Accountability, which measures not only academic progress, completion, and transfer, but also workforce outcomes for CTE students.

Conversations regarding student success specifically in CC STEM courses serving non-STEM majors should be identified and include the education research community, students, staff, faculty, and administrators through forums, conferences, and symposia. As CCs play an important role in training workforce students, we should also consider nationwide conversations with employers and workforce leaders via advisory boards to identify skills essential for STEM career readiness (Hirschy *et al.*, 2011; Jang, 2016). STEM educators may need to rethink how student success is assessed and explore how CUREs that focus on application of skills can be used to bridge gaps between current STEM education and desired workforce competencies (Jang, 2016). An NSF conference grant proposal could be one means to organize a group to define student success indicators or outcomes in CC STEM courses, which could drive the future design of CUREs to relate to these indicators or outcomes.

The unique student populations found at CCs may influence CURE implementation and, therefore, student outcomes. To differentiate the CURE approach, CC faculty should design CUREs to meet the goals of different CC student populations, including not only STEM majors, but also non-STEM majors, and workforce students. Depending on how a student population defines success, the implementation of CUREs to foster specific student outcomes may vary. A holistic approach for defining what success means at CCs will be conducive to implementing appropriate assessments and potentially capturing a larger repertoire of outcomes for students via CUREs. Future research could examine the extent to which CUREs are aligned with various definitions of success and whether CC students experience success. Learning from Bozinovic *et al.* (2021), we should use periodic self-assessments and student feedback to improve our evaluation methods by identifying and reducing biases, which negatively impact student learning and retention (Bozinovic *et al.*, 2021). For example, students studying in STEM fields who reported low confidence and obtained lower grades were less likely to persist (Bozinovic *et al.*, 2021). Arguably, how we assess student success needs revision, as well as scrupulous testing of interventions to foster a persevering mindset in STEM fields (Henry *et al.*, 2019). Addressing biases in assessments is not only applicable to CC students participating in CUREs but critical for understanding the differential impacts they have on CC students overall.

CONCLUSION

CCs train a large proportion of the STEM workforce, and yet, with few exceptions, workforce students are not included in STEM education research. If we want to increase representation in the STEM workforce and make informed curricular decisions, we must include CC and workforce students in CURE research. While CUREs have been reported to have positive student outcomes, it is yet to be identified which aspects of a CURE are beneficial at CCs and for which student populations. Trying to tease out the differential impacts CUREs may have for CC students is a major challenge, as CCs are microcosms, each with its own unique demographics. Therefore, we cannot make assumptions that CUREs benefit CC workforce students in the same manner as STEM majors. Furthermore, we should not rely on retrofitting instruments or data collected primarily at bachelor's degree–granting institutions to make assumptions about CURE outcomes and impacts on CC workforce students. As CCs are increasingly being called upon to implement high-impact educational practices such as CUREs, it becomes more critical to appropriately define and assess student success. Doing so can help better inform the institutions that provide funding and dictate policies and practices that impact CC students. Underrepresentation of CC perspectives in the literature perpetuates gaps in data, prevents meaningful comparisons for CCs, hinders our ability to better understand CC impact, and further limits CC faculty and student participation in undergraduate research. Based on the braided river model (Batchelor *et al.*, 2021) and our purview as educators, we call on the STEM community to re-evaluate how success is defined for CC students, use appropriate instruments for CC populations, and expand CURE implementation to be inclusive of workforce and underrepresented CC students.

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