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Broadening Participation in Biology Education Research: Engaging Community College Students and Faculty

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ABSTRACT

Nearly half of all undergraduates are enrolled at community colleges (CCs), including the majority of U.S. students who represent groups underserved in the sciences. Yet only a small minority of studies published in discipline-based education research journals address CC biology students, faculty, courses, or authors. This marked underrepresentation of CC biology education research (BER) limits the availability of evidence that could be used to increase CC student success in biology programs. To address this issue, a diverse group of stakeholders convened at the Building Capacity for Biology Education Research at Community Colleges meeting to discuss how to increase the prevalence of CC BER and foster participation of CC faculty as BER collaborators and authors. The group identified characteristics of CCs that make them excellent environments for studying biology teaching and learning, including student diversity and institutional cultures that prioritize teaching, learning, and assessment. The group also identified constraints likely to impede BER at CCs: limited time, resources, support, and incentives, as well as misalignment between doing research and CC faculty identities as teachers. The meeting culminated with proposing strategies for faculty, administrators, journal editors, scientific societies, and funding agencies to better support CC BER.

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THE URGENT NEED FOR COMMUNITY COLLEGE BIOLOGY EDUCATION RESEARCH

What would it mean for biology education research (BER) if a distinct group of colleges enrolling nearly half of all undergraduates was left unexamined? How would it complicate efforts to understand biology teaching and learning if these colleges enrolled the largest proportions of students of color, first-generation students, and other underserved groups? How might it impact national initiatives to increase student success if the faculty teaching these students did not have an opportunity to contribute to the body of educational research?

Almost half of all undergraduates are attending community colleges (CCs),[1] which also enroll the majority of all Latina/o, Native American, and Black undergraduates, and nearly half of all Asian and Pacific Islander undergraduates (American Association of Community Colleges [AACC], 2016). Further, more than half of all students receiving science, technology, engineering, and mathematics (STEM) bachelor's degrees complete some undergraduate training in CCs (National Science Foundation, National Center for Science and Engineering Statistics [NSF, NCSES], 2010). For these reasons, CCs have been broadly recognized for their potential to influence early undergraduate learning and to broaden participation in STEM among traditionally underserved student groups (Olson and Labov, 2012).

Despite the key roles of CCs in the higher education landscape, our initial observations suggested that the existing BER literature left CC contexts largely unexamined. Offerdahl *et al.* (2011) define BER as "hypothesis-driven research seeking to create new knowledge about the teaching and learning of biology and to disseminate that knowledge to the broader scientific community" (p. 12). BER plays a key role in national efforts to transform biology education (American Association for the Advancement of Science [AAAS], 2011; Offerdahl *et al.*, 2011; President's Council of Advisors on Science and Technology, 2012). Given that CCs are an "often overlooked but essential component in the U.S. STEM education system" (Olson and Labov, 2012, p. 2), we sought to investigate our initial observations about the underrepresentation of CCs in BER and better understand how this might impact efforts toward STEM education reform.

To evaluate the extent to which CC BER is underrepresented in the BER literature, we conducted a review of seven journals that regularly publish BER (Table 1). We included research articles, methods papers, features, and essays in our definition of BER (see Supplemental Material, Parts B–D, for review methods). We limited our review to articles published between January 2012 and September 2015 because a National Academies report (Olson and Labov, 2012) on the importance of CCs was highlighted in 2012 in a journal that primarily publishes BER (Labov, 2012). Only 3% of articles published since 2012, 57 articles total, included either CC authors or a CC biology study context (Table 1; see Supplemental Material, Part A, for a list of the articles found). This finding raised two key concerns:

1. As a BER community, we might be largely unaware of valuable teaching and learning strategies arising in CC biology contexts—particularly those related to advancing biology interest and learning among underserved student populations. In addition, we might lack an understanding of the assets and needs of CC students, who represent half of all biology majors nationwide (NSF, NCSES, 2010) and stand to benefit the most from advances targeting underserved students.
2. As advocates of pedagogical transformation, we must be concerned that a lack of CC faculty involvement in BER could hinder national efforts toward biology education reform. Many theories of change support the concept that faculty engagement in systematic evidence collection in their own teaching contexts is a key driver of change (Grunwald and Peterson, 2003; Prochaska and DiClemente, 2005; Handelsman *et al.*, 2007; Holme *et al.*, 2010). The relative lack of CC involvement in BER could represent a missed opportunity to promote change at the colleges that serve nearly half of all undergraduates.

TABLE 1. Representation of CC BER among all articles in seven BER journals sampled over a 3-year period[a]

Journal	Total papers	CC BER papers	% CC BER
Advances in Physiology Education	243	1	0.4
The American Biology Teacher	557	14	2.5
Anatomical Sciences Education	239	1	0.4
BioScience	36[b]	1	2.8
CBE—Life Sciences Education	249	7	2.8
Journal of College Science Teaching	257	17	6.6
Journal of Microbiology and Biology Education	196	16	8.2
Total	1741	57	3.2

[a]See Supplemental Material, Part A, for complete citations for all CC BER articles found.
[b]The total for *BioScience* includes only the number of education-related publications during the specified time period. *BioScience* includes many basic science articles, features, etc., that are unrelated to BER.

MEETING OF INDIVIDUALS REPRESENTING DIVERSE PERSPECTIVES ON CC BER

Given the importance and lack of CC BER, we convened a group of 24 stakeholders to examine the current state and future directions of CC BER. We aimed for our work to have broad and highly relevant impacts by ensuring that we had representation from institutions that reach diverse student groups, individuals who have expertise in equity issues, and individuals who themselves are from diverse backgrounds. These individuals, many of whom had published CC BER articles, served as editors for BER journals, collaborated in grant-funded efforts at CCs, facilitated professional development at CCs, or collaborated on action research in STEM, represented diverse institution types and geographic regions (see authors and affiliations listed on this report). The group included individuals of various racial and ethnic identities and many representatives of institutions with large populations of students from traditionally underserved backgrounds. The group also included non-CC and non-BER individuals who could provide strategic support and advice. For example, one individual was experienced in conducting action- and community-based participatory research. She offered insights into ensuring that CC needs would be

[1]CCs are defined as primarily associate's degree–granting, nonresidential colleges that offer training and classes that are affordable and relevant to the local community (Homeland Security, 2012).

addressed by CC BER conducted via collaborative efforts between CCs and external BER researchers. Journal editors additionally play a critical role in supporting and disseminating CC BER. The editors who attended our meeting advised us on how CC BER researchers could successfully engage in research publication and offered information about resources available to support CC BER. In recognition of the diverse and extensive contributions of the entire group, all meeting participants are included as authors of this report.

The Building Capacity for Biology Education Research at Community Colleges meeting took place in Denver, Colorado, on October 16–17, 2015, and was designed to achieve the following objectives:

1. Characterize the present state of CC BER
2. Identify areas ripe for exploration via CC BER
3. Identify characteristics that facilitate or constrain engagement in CC BER
4. Identify and prioritize strategies for supporting CC BER
5. Construct a networking resource for furthering efforts in CC BER beyond the meeting

In the following sections, we describe the results from the meeting related to each of these objectives.

EXISTING CC BER PUBLICATIONS FOCUS ON THE DISSEMINATION OF CURRICULA AND INCLUDE RELATIVELY FEW CC AUTHORS

We first sought to characterize the current state of CC BER by examining the 57 CC BER articles we had identified before the meeting. We categorized each article according to article type (Figure 1), main topic (Figure 2), and presence of a CC author (see complete methods for these analyses in Supplemental Material, Parts B–D). Ten of the 57 CC BER papers in our sample (18%), including six of the 28 "research articles" (21%), had no CC-affiliated coauthor (Supplemental Material, Part A). The 57 papers included a total of 136 instances of authorship, with 66 of those (49%) being individuals from CCs. In other words, a little more than half (51%) of CC BER authorship came from individuals not affiliated with CCs. It was not uncommon for CC-related research articles in particular to be authored exclusively by faculty from 4-year institutions.[2] Further, some of the 66 instances of authorship by CC faculty involved the same individuals publishing multiple papers. In total, 54 individuals affiliated with CCs published CC BER papers in these journals between 2012 and the time of our meeting. Nine CC individuals appeared on multiple papers in the sample.

In summary, our review of existing CC BER publications between 2012 and 2015 yielded three main findings:

1. A large percent of CC BER publications were research articles, but publications also included other forms of papers, such as teaching tips, essays, case studies, review articles, and editorials (Figure 1 and Supplemental Material, Part A).
2. Nearly all CC BER papers focused on topics regarding curricula or pedagogical methods; very few touched on issues of equity, diversity, and transfer (Figure 2 and Supplemental Material, Part A).

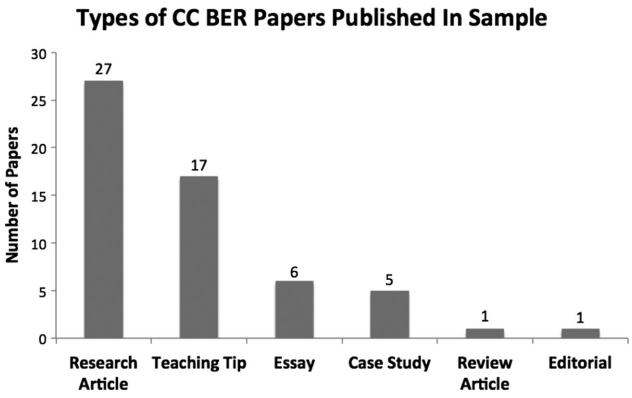

FIGURE 1. Types of publications included among the 57 CC BER papers in our sample. See Supplemental Material, Part D, for descriptions of publication types.

3. Fifty-four individuals affiliated with CCs authored CC BER papers during the period examined, and a little more than half of CC BER authors were faculty at 4-year institutions. More than 20% of CC BER publications categorized as "research articles" were authored exclusively by authors from 4-year institutions and had no CC-affiliated coauthors (Supplemental Material, Part A).

Given that CCs are lauded for their diverse student bodies and their potential to enhance equity in higher education (Olson and Labov, 2012), CC students are arguably in the best position to benefit from innovations and reforms that address equity and diversity in STEM. It was striking, then, to find so few CC BER papers specifically discussing those topics (Figure 2 and Supplemental Material, Part A). CCs represent promising venues for studying the development of science identities, examining interventions to broaden participation in STEM, and evaluating curricula connected to diverse cultures or social justice, among other topics. This might be accomplished simply by collecting and analyzing student demographic data in the context of instruction studies. Researchers could then analyze disaggregated data to determine whether students' experiences or

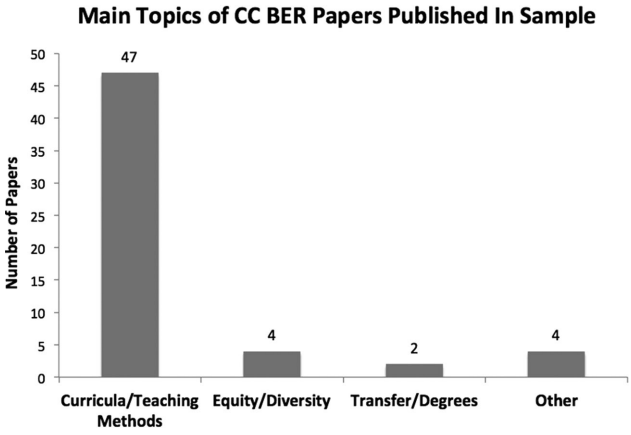

FIGURE 2. Main topics discussed in the 57 CC BER papers in our sample.

[2]We define 4-year institutions as baccalaureate colleges and PhD and master's degree–granting institutions.

outcomes are influenced by demographics. Such CC BER work on equity and diversity will be important to faculty at all levels of higher education, since CC student demographics provide a window into future demographics at 4-year colleges and universities (Hussar and Bailey, 2013).

Likewise, few papers addressed issues related to transfer of biology students between CCs and 4-year institutions. Identifying factors that influence transfer and the persistence and success of transfer students is a national priority. Only 33% of students who intend to transfer actually do so, and only 14% complete a bachelor's degree within 6 years (Jenkins and Fink, 2016). While prior work that broadly addresses STEM transfer may serve as a foundation to inform reforms for biology transfer students, specific work in biology is needed to capture the nuance of biology transfer students' experiences. This is especially important in understanding CC transfers' success in competitive pursuits such as admission to medical or graduate school.

We found that non-CC individuals were chiefly responsible for authorship of many CC BER papers. It is not surprising that 4-year faculty make substantial contributions to the CC BER literature, especially given that they are expected to publish scholarly work and are rewarded for doing so. Publications by 4-year faculty investigating CC contexts represent important contributions to the field, as they advance understanding of CC biology teaching and learning. However, failing to collaborate equitably with partners in a community under study, in this case with CC stakeholders, runs the risk of making community partners feel that the work was conducted upon them or that they were exploited. This can hamper the adoption of research-based innovations or result in resistance to future participation (Hacker, 2013).

In the spirit of attending to the unique cultures of CCs and driving institutional changes that might more directly benefit CC students, it is desirable to have CC representatives involved and invested in CC BER. CCs occupy a unique space in the education landscape, because they receive input from a greater array of stakeholders and are subject to pressures different from those at 4-year institutions (Nunley *et al.*, 2011). Involving CC faculty and administrators as collaborators, from study design through coauthorship, will ground methods and findings in the cultures of CCs and increase the relevance of the studies to the classrooms being examined. Additionally, engaging in a study of one's own classes frequently illuminates areas of dissatisfaction and motivates instructional innovation (Grunwald and Peterson, 2003; Prochaska and DiClemente, 2005; Holme *et al.*, 2010). If outside researchers are exclusively responsible for designing, conducting, and publishing CC BER, this could deprive faculty at CCs of opportunities to gain insights that would illuminate shortcomings of current practice and lead to pedagogical innovation. In consideration of the above, we propose that community-based participatory research (Hacker, 2013) could represent an effective model for maximizing the efficacy of CC BER collaborations between 4-year and CC stakeholders. (See *Community-Based Participatory Research (CBPR) as a Model for Designing CC BER* section.)

CONDUCTING DISCIPLINE-BASED EDUCATION RESEARCH AT CCS

Given the results of our review, we sought to identify factors that could be constraining CC BER studies and publications. We hypothesized that such constraints might include institutional and logistical barriers in addition to barriers related to faculty professional identities. At the same time, we hypothesized that CCs have a number of characteristics that could facilitate, support, or foster CC BER. We therefore set out 1) to identify characteristics unique to CCs that would facilitate CC BER and 2) to illuminate constraints to conducting such investigations.

What Characteristics Might Facilitate BER at CCs?

We identified four characteristics that we believe are broadly represented among CCs and could facilitate CC BER. Below we describe each and discuss their relationship to CC BER.

Characteristic 1: CCs Have Diverse Student Populations. The NSF, AAAS, National Academies, and other leading organizations have made broadening participation in STEM a national priority (Starobin and Laanan, 2010; AAAS, 2011; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine [NAS–NAE–IOM], 2011; NSF, 2014). Of particular concern is the shortfall in scientists from Black, Latino/a, Native American, and certain Asian and Pacific Islander backgrounds (Astin, 1993; NAS–NAE–IOM, 2011; Maramba, 2013). As noted earlier, CCs enroll the majority of these populations and are therefore ideally positioned to influence early undergraduate biology learning for many traditionally underserved student groups (Starobin and Laanan, 2010; Labov, 2012). Teaching innovations that benefit these groups can be developed and tested at CCs to inform best practices for inclusive biology education. These unique BER opportunities are of particular interest in the current funding climate. Recent calls for proposals from several NSF programs emphasize *broadening participation of individuals and institutions in STEM fields* (NSF, 2015). The Howard Hughes Medical Institute (HHMI) also seeks to make science *inclusive* and has encouraged collaboration between 4-year institutions and CCs (HHMI, 2016). Thus, researchers proposing to conduct CC BER are likely to encounter funding opportunities to explore equity, diversity, inclusivity, and student learning.

Characteristic 2: CCs Have an Existing Culture of Assessment. CCs regularly conduct assessments of student learning outcomes to maintain accreditation (Nunley *et al.*, 2011). As such, CC faculty might already have systematically collected and analyzed classroom evidence that could form the basis of CC BER. By engaging in regular pedagogical evaluation and reporting of outcomes, CC faculty have built knowledge and experience that could be applied to broadscale assessments and the reporting of educational data. This could make CC faculty strong collaborators in BER projects. In addition, by framing CC BER in the context of student success and the institution's required outcomes assessments, CC faculty might be able to rally institutional support for the additional time and resources needed to conduct BER.

Characteristic 3: CCs Include Workforce-Oriented Programs Not Commonly Found at 4-Year Schools. Many CCs house workforce educational programs in biotechnology, agricultural technology, and other bioscience-related fields. For example, NSF's Advanced Technological Education program targets CCs to fund technician education in high-demand

industries. These programs incorporate innovative teaching methods and routinely collect data to assess soft skills, lab skills, and student knowledge. Such workforce-oriented programs represent areas ripe for exploration via CC BER.

Characteristic 4: CC Instructors, Administrators, and Staff Focus Almost Entirely on Pedagogy for Both Traditional and Adult College Students. CC faculty are heavily invested in the topics CC BER seeks to address as daily practitioners and educators. Thus, they are likely to have unique practical insights and motivation to understand biology teaching and learning, both of which can drive CC BER. Furthermore, CC instructors typically teach many classes and run multiple course sections in parallel. As such, they may have more opportunities to iterate and improve their practices, replicate treatments, and conduct comparison group studies. Finally, smaller class sizes at CCs compared with the class sizes at many 4-year schools could lower logistical barriers associated with piloting novel curricular and instructional methods. For these reasons, CC instructors are well positioned to efficiently implement, evaluate, and reflect upon new interventions to promote learning among diverse groups of students.

What Constraints Might Impede BER at CCs?

Below we describe five categories of constraints that might limit CC instructors in conducting BER. By characterizing each constraint, we hope they can be further examined to ascertain whether they are indeed broad constraints, and how they might be avoided or mitigated. Our discussion of constraints focuses on those encountered specifically by CC faculty, because, as discussed earlier, it is of paramount importance to involve CC faculty in collecting and communicating evidence (Holme *et al.*, 2010). Other constraints and advantages may be encountered by 4-year or external researchers seeking to conduct CC BER; these are beyond the scope of this paper.

Constraint 1: CC Faculty Are Not Provided Time to Learn about or Conduct CC BER. Time was often discussed as a constraint. At CCs, faculty are not expected to conduct research (Cohen and Brawer, 2003, chap. 3), and thus are rarely allotted the time to do so. CC faculty have heavy teaching loads. Thus, course prep can be especially time-consuming for CC classrooms, which can include students with a wide variety of prior academic and science learning experiences. We recognized that those few CC faculty currently participating in CC BER are likely to have even more time commitments than colleagues, as they might more often choose, or be asked to, participate in curricular revisions, program assessments, and other extra assessment-related responsibilities (Bush *et al.*, 2011). Gaining expertise in *how* to conduct BER also requires significant time. The group recognized that, for CC faculty who are fully employed, gaining BER training usually requires "on-the-job" training via self-instruction, trial, and error. However, the time and resources available for self-education are limited and generally require personal time investment by the faculty. Access to mentorship in BER is often not available, as limitations in time among current BER scholars may prevent them from engaging with interested CC faculty. Thus, lack of time among both interested CC faculty and those who could help them is likely a common obstacle to engaging in CC BER.

Constraint 2: CC Faculty Have Limited Access to the Infrastructure Necessary to Conduct BER. Lack of infrastructure, including funding, administration (e.g., institutional review board [IRB] offices), research tools (e.g., statistical programs), and information (e.g., access to journals), was discussed as a key factor limiting CC faculty engagement in BER. Although funding limits most research, the group felt that CC faculty are particularly poorly positioned to garner and spend extramural funds. National and private funds are available to conduct CC BER and, compared with other forms of research, BER is low cost. Yet the group expressed low awareness of how to find and apply for funding. Funding structures, programs, and calls are continually shifting, and must be relearned on a yearly basis, and there are rarely systems in place to help CC faculty learn about funding opportunities. CC faculty generally work unassisted to find opportunities, determine whether they are eligible, and learn how to compete for funds. Any new funding opportunities for CC BER should take this into account and make efforts to remove bureaucratic barriers.

Additionally, in comparison with other educational institutions, CCs have lower access to information and technology infrastructure, including research journals, BER texts, data-collection and analysis programs, computing resources, and other instrumentation to assist with research. The lack of access to articles and informative texts is especially problematic, as it limits access to information faculty could use to teach themselves common BER practices, inform their research questions, and prepare proposals. The group noted that this places a higher burden on CC faculty to obtain these resources compared with faculty at 4-year institutions.

CCs often lack administrative infrastructure to support CC BER. The most frequently discussed administrative limitation was the lack of an IRB. Research with human subjects requires IRB exemption or approval to be considered for publication, and very few CCs have IRB offices. As such, obtaining IRB approval often necessitates collaboration with other institutions. Such partnerships can be difficult to build, as IRBs at 4-year schools are often overworked and unable to consider proposals beyond those arising from in-house projects. In addition, CCs do not have grant offices that help faculty find, obtain, and manage funding. This can result in CC faculty having no mechanism through which to submit proposals and manage awards. Our consensus was that addressing constraints in administrative infrastructure will be paramount in increasing CC BER conducted by CC faculty.

Constraint 3: CC Faculty Lack Administrator and Peer Support for Conducting BER. For CC faculty and staff, conducting research of any type is generally not an explicit job expectation (Cohen and Brawer, 2003, chap. 3). Thus, conducting CC BER may be viewed as at odds with the expected roles of a CC faculty member. This can create confusion and even interpersonal conflict in the professional relationships of CC faculty engaging in CC BER. A common criticism of required accreditation-related assessments has been that such assessments and reports impinge on academic freedom by forcing faculty to match their teaching to whichever person produces the "best" assessment data (Cain, 2014). The group noted that similar concerns may arise between CC faculty involved in CC BER and their colleagues. Some colleagues might be concerned that CC BER

faculty are simply trying to prove that their way of teaching is the best and should be followed by others. This fear might be intensified by the fact that CC faculty are not required to perform research, and therefore, despite their good intentions, they may be perceived as having self-serving motives in taking extra effort to engage in CC BER. Even if colleagues are unlikely to express these views, the fear of encountering such emotions may be enough to prevent interested CC faculty from engaging in CC BER. Likewise, the group agreed that administrators may see CC BER as unnecessary or unrelated to instructors' primary duties and may feel that it detracts from explicit teaching and service expectations. Further, they may fear that results of CC BER research may highlight flaws in the system, which may then require costly solutions. As managing budgets and employee time are central responsibilities of administrators, they may see it as in the best interest of their institutions to discourage CC BER. Thus, faculty conducting CC BER may find themselves in a place of needing to explain and defend their work to both colleagues and supervisors.

CC faculty who experience little collegial support in their institution can seek support from other BER researchers. However, this presents other challenges. Currently, the CC BER community is relatively small and geographically scattered; it is hard to easily meet and regularly interact with other CC individuals who study biology teaching and learning. As noted earlier, we identified only 54 CC individuals who authored CC BER papers in our sample, and those individuals were geographically dispersed across the United States. In addition, not all CC faculty have access to funds to attend national conferences in their discipline; they are not necessarily expected to participate in such activities. We agreed that these challenges, when combined, make forming external networks and collaborations challenging.

Constraint 4: CC Faculty Experience a Misalignment between Professional Identity and Research Identity. The group proposed that most CC faculty have a strong "teaching identity," as teaching constitutes the bulk of their work, and a less strong or even absent "research identity." Prior work on CC instructor identity agrees with this conclusion (Cohen and Brawer, 2003, chap. 3). This could result in internal conflicts regarding which professional activities to prioritize, similar to the conflicts described for research university faculty by Brownell and Tanner (2012). The group recognized that CC faculty may feel that they are not as experienced at research and therefore might not be able to contribute effectively. Participants also mentioned that unpleasant prior experiences with research may motivate CC faculty's choice of a profession in which there is no explicit expectation of research. Thus, low research self-efficacy and lack of research identity may lower motivation and prevent CC faculty from engaging in BER (Pajares, 1997). This may seem surprising, considering that CC biology departments hire individuals with graduate degrees who have performed research and that the activities associated with educational assessment are closely aligned with research. However, self-efficacy and identity are strong indicators of one's professional motivations and actions (Bandura, 1986; Schunk, 1995; Pajares, 1997). These factors may represent subtle yet powerful obstacles to the engagement of more CC faculty in BER.

Constraint 5: There Are Few, If Any, Formal Incentives or Rewards for CC Faculty to Conduct or Publish BER. While noteworthy exceptions exist (e.g., Kingsborough Community College, NY, and Kapiolani Community College, HI), there are typically no formal expectations for CC faculty to conduct and publish research—BER or otherwise (Cohen and Brawer, 2003, chap. 3). Many 4-year universities, on the other hand, highly incentivize conducting and publishing research, resulting in a greater amount of time, effort, and funds being spent on research endeavors and much higher research productivity. Because professional expectations and incentive structures emphasize teaching and service, CC faculty are likely to prioritize those activities over research in their daily practice. Thus, the group noted that, barring a change in current formal incentive structures, CC faculty may need an incentive beyond work responsibilities to conduct BER.

What Can Be Done to Alleviate or Circumvent These Constraints?

The group proposed a number of strategies to mitigate the effects of these constraints. It was agreed that all interested individuals could support CC BER by clarifying its value for colleagues, administrators, and funding agencies. For example, CC BER is useful because…

- it draws upon the minds and talents of CC instructors to inform biology education broadly;
- it allows investigation of biology teaching and learning among highly diverse populations of students;
- it informs instructional practice at CCs; and
- it promotes student success by providing insights that will guide interventions and programs in the institutions that serve nearly half of all undergraduates.

Table 2 describes specific ways in which funding agencies, BER societies, journal editors, administrators, and 4-year/CC faculty might support CC BER. Several strategies are likely to address multiple constraints. For example, mentorship by experienced BER researchers would likely help CC faculty gain access to resources, develop research skills and self-efficacy, and gain social support. The *Several Current Efforts Support CC BER* section includes examples of some of these strategies in action.

It is important to note that not all support strategies can be implemented by CC faculty or even by CC administrators. For example, while CC faculty can advocate for incentives such as course release or CC-specific grants, they are not often in roles that have direct influence in creating and distributing these incentives. Furthermore, many CC faculty are not in roles that carry sufficient clout to be highly effective advocates for CC BER. Adjunct instructors, who make up large proportions of the faculty at CCs, often do not have significant decision-making power. For these reasons, the effort to increase CC BER must include individuals in multiple roles with varying spheres of influence.

Community-Based Participatory Research (CBPR) as a Model for Designing CC BER

We propose that CBPR could be applied as a way to encompass many of the support strategies in Table 2 to alleviate constraints on CC BER while ensuring CC stakeholders play lead roles in driving research. As discussed following our analysis of existing

TABLE 2. Proposed strategies to alleviate, eliminate, or help faculty to avoid constraints on completing CC BER

Advocate role	CC BER support strategies
BER funding agencies	Increase external awards and resources for CC BER researchers • Issue calls for proposals centered on CC BER needs • Fund professional development for CC faculty Craft program solicitations to explicitly encourage community-based participatory research (CBPR) involving CC researchers • Reduces the potential for CCs to be included in grants solely to enhance the attractiveness of proposals rather than serve the needs of the CCs Develop resources to support CC faculty in conducting CC BER • For example, assist with the initial development of a centralized IRB that serves many CC campuses Bring together CC BER stakeholders, and specifically CC administrators, to generate ideas and provide feedback • Advocate for top-down support of CC BER by reaching out to CC senior administrators Involve CC stakeholders in broad efforts to improve biology and STEM education • Sustain efforts to involve stakeholders from all institution types in next steps in STEM education reform (e.g., *Vision and Change* [AAAS, 2011] and the PULSE community [www.pulsecommunity.org])
Leaders and members of networks in BER (e.g., organizers of national meetings or online communities)	Increase opportunities for CC faculty to network within the BER community • Advertise activities and opportunities in CC faculty circles • Take into consideration the schedules and obligations of CC faculty • Create events specifically for CC faculty to build networks of individuals with common experiences and identities • Bring on CC stakeholders in advisory roles • Provide support for CC faculty to engage in meetings and networks • Offer travel awards or reduced registration fees for CC faculty • Formally recognize CC faculty exhibiting excellence in teaching and contributions to BER during meetings
Journal editors	Formally recognize CC faculty exhibiting excellence in BER Develop resources to support CC faculty in conducting and publishing CC BER • Survey CC contributors to determine what information and resources authors would find helpful • Include this information in publicly available advice to authors • Hold Q&A sessions at national meetings, CC-specific events, or online webinars for CC faculty to learn about the publishing process Provide dedicated spaces to highlight CC BER • Create CC BER feature issues • Introduce CC-specific columns • Issue calls for investigations done at CCs Promote CBPR as a model for collaborations involving CCs • Encourage 4-year investigators with an interest in CC BER to include CC stakeholders as collaborators and coauthors
CC administrators	Showcase BER efforts in program assessments and evaluations • Count CC BER toward an instructor's required contributions to accreditation, program review, and equity-related efforts • Make available resources associated with those efforts to faculty conducting CC BER Increase incentives for conducting CC BER • Offer release time or professional development funds as incentives to those wishing to engage in CC BER Increase rewards and honors for CC BER researchers • Open additional laboratory, classroom materials, or travel funds for faculty engaging in CC BER • Nominate CC BER faculty for national or institutional awards • Highlight CC BER efforts at the institution in newsletters or campus-wide events Develop resources to support CC faculty in conducting CC BER • Construct shared resources in support of BER (e.g., regional IRB) across colleges/campuses
Experienced BER researchers from 4-year institutions	Offer professional development for individuals interested in CC BER • Provide professional development in how to collect and analyze data, prepare data for publication, and conduct multiyear or multiclass studies Involve CC stakeholders in advisory boards for advice on projects including CC contexts Collaborate with CC researchers on BER projects of interest to both parties • Ground collaborations in CBPR to ensure research is mutually beneficial and effects change for all partners • Offer access to resources absent at CCs (e.g., journals, IRB offices, statistical software) • Distribute workload to leverage capacities and interests of CC students, faculty, or administrators

Continued

TABLE 2. Continued

Advocate role	CC BER support strategies
Experienced BER researchers from CCs	Offer professional development in CC BER focused on CC-specific challenges and opportunities. For example, • Navigating data collection and analysis for lower-enrollment courses • Leveraging existing CC administrative structures for BER • Balancing CC BER and teaching load Nucleate an institutional or regional community of CC individuals interested in BER • BER journal clubs • Sharing classroom evidence-collection strategies • Exploratory collections of evidence on a common research question across classrooms Mentor other CC faculty in exploring BER • Experienced CC BER researchers have insight into what questions are most relevant for entering researchers to pursue, the advantages and pitfalls of conducting CC BER, and the nuances of working within the broader BER community
CC faculty interested in engaging in CC BER	Form journal clubs to discuss current BER work Approach administrators to see how CC BER might fit into existing programmatic or institutional needs • Frame CC BER as part of existing institutional initiatives • Explore resources that might exist for contributions to accreditation, equity initiatives, or program reviews Access online resources about how to conduct BER. For example, • *Discipline Based Education Research: A Guide for Scientists* (Slater *et al.*, 2011) • *Discipline Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering* (Singer and Smith, 2013) • Enhancing Scholarly Work on Teaching and Learning: Professional Literature That Makes a Difference (Weimer, 2006) • Scientific Research in Education (Shavelson and Towne, 2002) • Grappling with the Literature of Education Research and Practice (Dolan, 2007) Initiate Scholarship of Teaching and Learning (SOTL) efforts as a gateway to BER • SOTL papers are typically more narrowly focused than BER, often focusing on a single activity in a single classroom (Offerdahl *et al.*, 2011) • Provides a manageable stepping-stone to more in-depth BER Capitalize on the unique assets of CCs related to BER • Use existing assessment practices as a starting point for BER or SOTL • Collect demographic data and disaggregate assessment results to examine how student learning varies by student group • Reach out to institutional researchers for tools and advice Initiate collaborations with CC faculty at other CCs • Provides social support from colleagues in similar positions • Allows pooling of resources and capacity • Increases sample sizes if collaborating on a common project Initiate collaborations with university BER and education researchers • University BER researches are often interested in CC contexts, but lacking in CC connections • University education researchers and psychologists are often excited to work directly with STEM faculty and bring expertise in social science techniques • Potential access to journals, IRBs, etc. Invite CC students to collaborate on BER or SOTL projects • Provides CC students opportunities for authentic research experiences • Helps to distribute work among many hands • Students bring unique insights and contributions as it relates to assessing their college

CC BER articles, only a relatively small number of CC individuals appear to be actively publishing CC BER. Because many of the constraints identified by the group involved a lack of resources (e.g., infrastructure, experience, peer support), partnerships in which CC faculty seek out 4-year collaborators with access to these resources represent an obvious potential solution. Some funding solicitations have explicitly encouraged such partnerships (HHMI, 2016) or even provided opportunities for additional funding if CC faculty hold leadership roles in a proposal (NSF, 2009). The presence of special sections on CC work in journals (e.g., Two-Year Community in *Journal of College Science Teaching*) and the presence of articles in BER journals encouraging partnerships between CCs and 4-year schools (Labov, 2012) additionally convey to 4-year partners a heightened interest by journal editors in representing the CC perspectives and strengths in studies.

While the group lauded these efforts as critical steps for encouraging CC BER, we also noted potential drawbacks. Specifically, there is potential for 4-year researchers to seek out CC contexts simply in hopes of raising the appeal of grant proposals or

manuscripts, without further rationale for bringing on a CC partner. Indeed, several meeting participants recalled receiving out-of-the-blue invitations to collaborate on grants, sometimes only days before a deadline. While such overtures are made with good intentions, a failure to equitably partner with CCs by including them during every stage of proposal or study development could decrease the relevance of research findings to CC contexts and limit the adoption of research-based practices by CC stakeholders (Hacker, 2013).

CBPR holds promise as a way to construct more balanced CC–4-year BER partnerships such that positive outcomes are observed in both contexts. CBPR has been used in many contexts, including psychology, education, and public health to build trust among research partners and enhance the relevance of findings to communities under study. Interpreting the ideas of Israel *et al.* (1998), Hacker (2013) characterizes CBPR as an approach that

- acknowledges community as a unit of identity;
- builds on strengths and resources within the community;
- facilitates collaborative, equitable partnerships in all phases of research;
- fosters colearning and capacity building among all partners;
- integrates and achieves a balance between knowledge generation and intervention for the mutual benefit of all partners; and
- disseminates results to all partners and involves partners in the wider dissemination of results.

As it relates to conducting and publishing CC BER, these principles would recommend collaboration between CC and 4-year partners from question generation through publication. Of course, the level of involvement of each partner in one or another area of research could vary depending on the nature of the project. Given the high level of involvement of all partners, however, participation in a CC BER partnership using a CBPR approach would likely be based on an early collaboration between CC and 4-year partners and the expectation that both CC and 4-year partners coauthor resulting papers. The group also agreed that empowering CC faculty to define their own research interests and subsequently seek partnerships with interested 4-year faculty could place CC faculty in central leadership roles, ensuring relevance of the research for the CC community. In other words, 4-year representatives need not always hold the primary leadership roles in CC–4-year CBPR collaborations.

While CBPR is not appropriate in every instance, its potential to broaden the impacts of research and ground study findings in the cultures and identities of all research partners make it an attractive option for CC BER. We therefore encourage future initiatives at BER funding agencies and BER journals to advocate for CBPR as an approach for forging 4-year–CC partnerships. We additionally hope CC and 4-year faculty approach future collaborations using CBPR.

Several Current Efforts Support CC BER

Despite these challenges, steps have been taken in recent years to involve CC faculty in efforts to conduct BER and transform STEM education. For example, in 2011 *Vision and Change in Biology Education* actively recruited CC faculty to help define the content and scope of the report (AAAS, 2011). Also in that year, CC faculty were recruited by NSF to discuss how to best fund CC education initiatives (AACC, 2011). Increasingly, prominent individuals and organizations have sought to highlight CC STEM instruction in national conversations about science education (e.g., Fletcher and Carter, 2010; Labov, 2012). These efforts express consensus regarding the value of CCs for biology education and desire for more research in this area.

BER journal editors also recognize the need to expand representation of CC authors. Indeed, editors of four prominent BER journals (*Advances in Physiology Education*, *CBE—Life Sciences Education*, *Journal of College Science Teaching*, and *Journal of Microbiology and Biology Education*) participated in this meeting and are authors of this report. The staff at these and other BER journals implement strategies to include CC authors. All four journals draw upon the expertise of CC contributors as authors and reviewers. Some journals provide specific venues for CC contributors, such as the Two-Year Community column in the *Journal of College Science Teaching*. CC faculty are editorial board members of some journals such as *CBE—Life Sciences Education* and the *Journal of Microbiology and Biology Education*. Furthermore, in an effort to make publication accessible for all BER scholars, many journals include author instructions on how to approach different types of articles and take a hands-on approach in helping new authors refine their submissions. That many BER journals make their articles freely available helps to mitigate constraints surrounding journal access at CCs. These factors facilitate successful submission of articles and allow new BER scholars to participate as researchers and readers.

A growing number of networks within biology education and BER actively recruit and support CC biology educators. For example, the Society for the Advancement of Biology Education Research (SABER, https://saber-biologyeducationresearch.wikispaces.com) welcomes CC faculty at its annual meeting and includes an active listserv for sharing resources and ideas. Efforts are underway to make SABER meetings more accessible to CC faculty and to create a formal community of SABER CC scholars. Other networks provide training. The Biology Scholars Program (www.facultyprograms.org/index.php/biology-scholars-hybrid-courses) through the American Society for Microbiology provides training in conducting education research and publishing findings. Part E of the Supplemental Material for this report includes references to additional programs that connect CC biology faculty to larger communities of educators in ways that could support educational research.

Finally, several recent funding calls have encouraged STEM innovation and BER at CCs. At the NSF, the Improving Undergraduate STEM Education (IUSE), Advanced Technological Education (ATE), and Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES) programs all encourage proposals from and collaborations with CCs. Though it does not directly fund community colleges, the HHMI Inclusive Excellence program encourages collaborations between CC and 4-year institutions. Such funds could both provide material support for CC BER and fund reassigned time or stipends for CC faculty. NSF program officers recognize CCs as key players in these efforts due to the extensive diversity embodied at their institutions (AACC, 2011; NSF, 2016). Thus, they hope to actively involve the CC community in curricular innovation and in BER. However, more needs to be done to make CC faculty aware of these opportunities and

build enthusiasm and support for faculty-led grant work among CC administrators.

CONCLUSIONS

We view CC BER as a tremendously exciting area for exploration with enormous potential to uncover unique perspectives on biology education and foster innovation that could enhance CC student success and assist in diversifying STEM programs. Stakeholders at every level have reason to share in this excitement. Through CC BER, CC faculty and administrators can come to better understand their classrooms and institutions and highlight their colleges' accomplishments on a national stage. Four-year faculty can explore the strengths and needs of their transfer students, while pursuing new partnerships, exciting questions, and new funding opportunities and sharing insights for teaching beginning students. Funders can attract a critical segment of higher education institutions to national efforts in science education reform. Journal editors can broaden their journals' readership and extend their journals' influence in new contexts. CC students themselves can benefit from instructors' efforts to study innovative strategies in their classes and generate opportunities to participate in undergraduate research in BER. Indeed, all stakeholders will benefit from an increased understanding of biology teaching and learning in the institutions serving some of the most diverse student populations in the world.

Through the Building Capacity for Biology Education Research at Community Colleges meeting, we have characterized existing CC BER and provided recommendations for future work that might take advantage of assets in the CCs while also attending to challenges. Research and evaluation studies are necessary to fully explore the hypothesized opportunities and constraints described earlier and to determine the effectiveness of the strategies we propose to foster CC BER. We hope that the concrete steps described in Table 2 offer a productive starting point for increasing the prevalence of CC BER in the near term. We look forward to continuing these efforts and engaging new collaborators in this important work to broaden participation in BER.

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