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Characterizing Biology Education Research: Perspectives from Practitioners and Scholars in the Field

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Biology education research (BER) is a recently emerging field mainly focused on the learning and teaching of biology in postsecondary education. As BER continues to grow, exploring what goals, questions, and scholarship the field encompasses will provide an opportunity for the community to reflect on what new lines of inquiry could be pursued in the future. There have been top-down approaches at characterizing BER, such as aims and scope provided by professional societies or peer-reviewed journals, and literature analyses with evidence for current and historical research trends. However, there have not been previous attempts with a bottom-up approach at characterizing BER by directly surveying practitioners and scholars in the field. Here, we share survey results that asked participants at the Society for the Advancement of Biology Education Research (SABER) annual meeting what they perceive as current scholarship in BER as well as what areas of inquiry in the field that they would like to see pursued in the future. These survey responses provide us with information directly from BER practitioners and scholars, and we invite colleagues to reflect on how we can collectively and collaboratively continue to promote BER as a field.

KEYWORDS biology education research, discipline-based education research, research trends

PERSPECTIVE

Biology education research (BER) is an emerging field with increasing participation through journal publications and growing professional networks. As an example, the inaugural volume of the Journal of Microbiology and Biology Education (JMBE) in 2007 had four articles, a number that increased to almost 80 articles published in 2020 alone. There has been a concomitant increase in the number of people who identify as members of the BER community, as evidenced by increasing participation in various BER conferences. The BER community includes both BER practitioners (instructors who apply instructional practices based on BER and/or participate at BER conferences) and BER scholars (researchers who conduct BER studies); in many instances, an individual can be both a BER practitioner and a BER scholar. Therefore, we use these terms not to delineate distinctions in our community but rather to be inclusive and encompass all individuals who identify as members of the BER community. As the field continues to grow, it is important to reflect as a community on how members of the BER community perceive the work that is being done in BER.

Compared to related fields of discipline-based education research (DBER) in chemistry, physics, engineering, and mathematics, BER has only recently developed into its own distinct field (1, 2). DBER has a "deep grounding in the discipline's

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priorities, worldview, knowledge, and practices" (2). Therefore, BER—much like other DBER fields—is deeply rooted in an understanding of the biological sciences and thus the research perspectives and training of biologists (3). As a field, BER connects methodological and theoretical traditions from DBER, science education research, and other social science fields with the goal of improving learning and teaching in biology (4, 5).

Understanding how practitioners and scholars perceive the field can provide insight into what research questions are currently being pursued and what potential gaps exist in the work currently being done in BER. We present this perspective to foster discussions within our community and not as a commentary on what the field should encompass or pursue. Rather than being exhaustive or exclusionary, our hope is to provide some necessary information to spark introspective conversations within the BER community about our developing identity as a field and to identify potential opportunities for new explorations and interdisciplinary collaborations that will further strengthen BER and thus learning and teaching in biology.

PREVIOUS SCHOLARLY ATTEMPTS AT CHARACTERIZING BER

Several studies have attempted to describe the scholarship produced in BER, which provide important data for the community to reflect on what areas are being pursued in BER, how the field is developing over time, and what gaps in scholarship exist that may present new opportunities (1, 3, 6). These studies typically take one of two approaches. First, the top-down approach involves a limited number of individuals (e.g., from a journal or professional society) outlining the bounds and goals of the field (5, 7–13). For example, JMBE as a journal publishes "articles addressing good pedagogy and design, student interest and motivation, recruitment and retention, citizen science, faculty development, and institutional transformation" and describes itself as "rooted in microbiology and its branches to other biological disciplines" (14). Similarly, at the inaugural meeting of the Society for Advancement of Biology Education Research (SABER), its founding members defined 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" (6).

Subsequent studies have utilized a second approach that relies on analyses of presentations at BER conferences and published work in journals to identify trends, revealing that the field has shifted from descriptive studies of teaching material to analytical and quantitative studies of student learning largely in the undergraduate classroom (1, 3, 15). For instance, an analysis of the BER literature from 1990 to 2010 revealed that the most common BER studies "were based on implementing active learning strategies and determining the outcomes of such treatments on student learning" (1). Another study analyzed a broader history of the field since the 1920s and identified that initial BER studies focused primarily on examining the efficacy of instructional strategies but have now since expanded with an increasing number of studies on student learning (15). A more recent study observed that BER studies focusing on mechanistic questions of "how and why for inclusion, learning, and teaching in biology education" have only begun to emerge recently (3). Yet another literature analysis identified that BER papers from 1997 to 2014 focused on the subfields of environment and ecology, genetics and biotechnology, and animal form and function (2). Together, these efforts are situated in the broader literature that has examined published work in DBER across science, technology, engineering, and mathematics (STEM) disciplines (16–19) or focused on different active-learning strategies (20–23).

However, neither of these approaches directly consider how BER practitioners and scholars view the field. To democratize the process and increase the number of voices in this conversation, we present this perspective to further discussions within our community about BER. This bottom-up approach draws upon the network of practitioners and scholars in a field to characterize that field, has previously been used in other disciplines, and is particularly important for an emerging field such as BER, where the focus may still be shifting (24–26). Characterizations of BER from the bottom-up approach offer a complementary view to the top-down approach relying on a limited number of individuals and the literature analyses based on published work. As a growing field, BER is likely attracting an increasing number of new practitioners and scholars (3) who may not have published in BER but are nonetheless involved in the community, rely on BER to shape their pedagogies, and may pursue further scholarly work in the field in the future. It is important to engage BER practitioners and scholars more broadly to understand our perceptions as a community. Furthermore, by asking BER practitioners and scholars what work they think that the field should focus on, such characterizations can offer a forward-looking view, potentially revealing important areas of BER to be studied in the future.

SURVEY OF BER PRACTITIONERS AND RESEARCHERS

To include perspectives of BER practitioners and researchers in characterizing the field, we surveyed participants at the 2016 SABER annual meeting during the opening plenary session ([194/284] 68.3% response rate). We recognize that such a convenience sample from one society and one meeting represents a limited subset of individuals and does not encompass the voices of all BER practitioners and scholars. However, our work here is not meant to be exhaustive; instead, we provide these exploratory data in the hopes that they will spark conversations in our community about how practitioners and scholars may perceive the field.

We asked respondents how they would define BER (Fig. 1 and Table 1). Open-ended responses for each of the questions were coded by two of the authors with high interrater reliability (Cohen's kappa = 0.84). More than three-quarters of

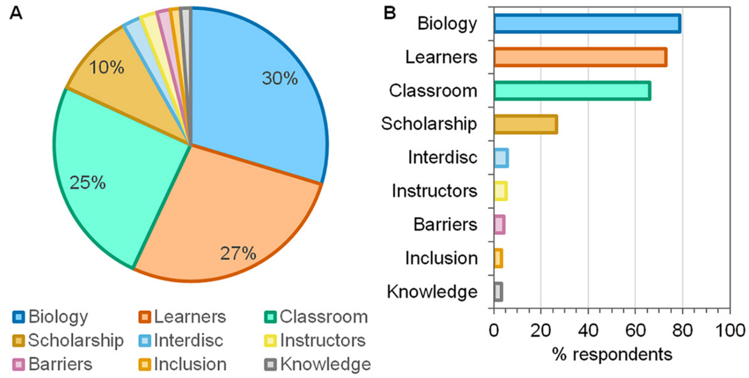

FIG 1. Respondents' definitions of BER. (A) Pie chart showing the percentage of each code from the total number of coded segments (*n* = 502, coded from 194 total responses). Each response could be described by more than one code. Percentages of <5% are not indicated. (B) Bar graph showing the percentage of respondents (*n* = 194) who provided a response described by each code. Responses could be described by more than one code, and the percentages sum up to >100%.

respondents (79%) mentioned the field of biology in their definitions, and almost two-thirds (66%) identified classroom practices, which were the most common responses. Our survey further revealed that BER practitioners and scholars take a student-focused (73%) rather than instructor-focused (5%) perspective, where the field is largely defined as an investigation of the role of students (or learners) in their own education and assessment of factors that shape their understanding of biology. Approximately one-quarter of respondents (26%) highlighted the scholarly aspect of BER, such as applying the scientific method to biology education, using an empirical approach to investigate what works or does not work in the classroom, or studying the scholarship of teaching and learning.

When asked to identify the purpose of BER (Fig. 2 and Table 2), almost two-thirds (64%) of respondents said that BER was meant to improve teaching practices, and more than half (59%) stated that BER was meant to improve student learning, the two most common responses. In contrast, less than one-fifth (19%) stated improving the educational structure at an institutional level as a purpose. Other responses (all <25%) include empirically studying biology education, improving scientific literacy of students and in society, increasing access and inclusion in biology education, preparing students for future careers, or identifying barriers to student learning and success.

These survey results demonstrate that BER scholars and practitioners largely view the field as focused on changing instruction to improve student learning, a finding that is in alignment with past analyses of BER papers and conference presentations. For example, the National Research Council report on DBER emphasizes that BER involves studying issues in the learning and teaching of biology (6, 27), consistent with our survey responses. Analyses of published and presented work in BER have likewise found that most studies are about examining and understanding student learning (1–3). Thus, while our work is potentially limited as a convenience sample, our results from this bottom-up approach show that BER practitioners and scholars hold similar views of the field, as was previously described in other work using top-down approaches or analyses of behaviors in BER.

We further asked what scholarship respondents saw currently being conducted in BER and what BER scholarship should

TABLE 1
Summary of codes for defining BER as a field

Code	Definition
Biology	Mentions the field of biology
Learners	Investigates the role of students (or learners) in their own education and assesses factors that shape their learning
Classroom	Investigates classroom practices to aid in student learning
Scholarship	Applies scientific method to BER to investigate what works and what does not in education
Interdisciplinary (interdisc)	Utilizes frameworks or methodologies from other disciplines to enhance BER
Instructors	Investigates the role of instructors in biology education
Barriers	Investigates factors that may negatively impact student learning or academic performance
Inclusion	Makes education more accessible and inclusive to everyone regardless of background
Knowledge	Seeks to determine or identify research methods to determine the extent of students' current knowledge

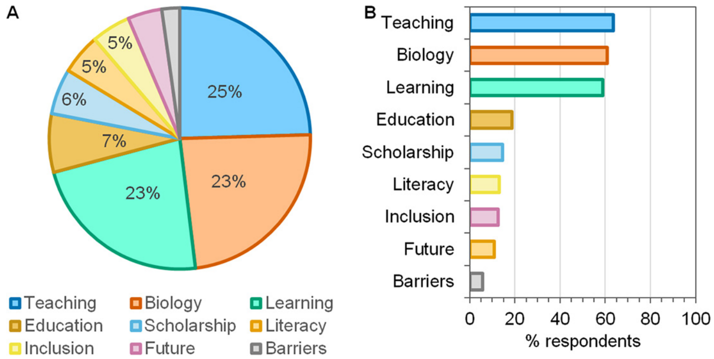

FIG 2. Respondents' descriptions of the purpose of BER. (A) Pie chart showing the percentage of each code from the total number of coded segments ($n = 497$, coded from 194 total responses). Each response could be described by more than one code. Percentages of <5% are not indicated. (B) Bar graph showing the percentage of respondents ($n = 194$) who provided a response described by each code. Responses could be described by more than one code, and the percentages sum up to >100%.

be pursued in the future (Fig. 3 and Table 3). Respondents viewed current scholarship as focusing on developing classroom interventions (45% of all coded segments) and assessing student outcomes (33%). Fewer responses indicated current work on expanding research approaches in BER (13%) or examining issues related to diversity, equity, and inclusion (8%). For future scholarship, responses indicated that BER should have a shifted focus: less on classroom interventions (from 45% to 35%) and student outcomes (from 33% to 16%) but more on research approaches (13% to 30%) and inclusion (8% to 10%). Intriguingly, no responses indicated that BER scholarship is currently working to determine the broader impact of the field (i.e., establishing BER as a legitimate field of study and contributing to education beyond postsecondary institutions); however, 8% of responses perceived this as an area of future scholarship.

Practitioners and scholars also provided insights on research approaches. More than one-half of the coded segments for current scholarship were related to developing instruments to assess student learning, whereas responses indicated that future scholarship could broaden its focus by adapting frameworks or methodologies from other disciplines to enhance BER, expanding study populations to include currently understudied demographics such as community college and transfer students, and following student development beyond the scope of a single course.

POTENTIAL NEXT STEPS AS A COMMUNITY

These survey results suggest some possible next steps for us as a community of BER practitioners and scholars. First, survey responses indicated a potential need for expanding research approaches in BER in the future, including more interdisciplinary scholarship. BER and DBER in other STEM disciplines share the common goal of improving learning and teaching, rely on the same social science methodologies, and are situated in disciplinary content knowledge that is already intertwined (5). Similarly, the field of education includes studies on the learning sciences, which encompasses work on how students learn and develop in

TABLE 2
Summary of codes for the purpose of BER as a field

Code	Definition
Teaching	To improve teaching practices implemented by instructors
Biology	Mentions the field of biology
Learning	To improve student learning
Education	To improve education in general, targeting the structure or system of education such as the institution
Scholarship	To apply the scientific method in BER and use an empirical approach to investigate what works and what does not
Literacy	To improve students' ability to apply biology knowledge in the real world or improve scientific literacy in non-STEM students
Inclusion	To make education more accessible and inclusive to everyone regardless of background
Future	To enhance students' educational experience to better equip students for their future endeavors
Barriers	To identify factors that influence student learning, including challenges, barriers, or general factors that contribute to the ability (or lack thereof) of a student to learn the material

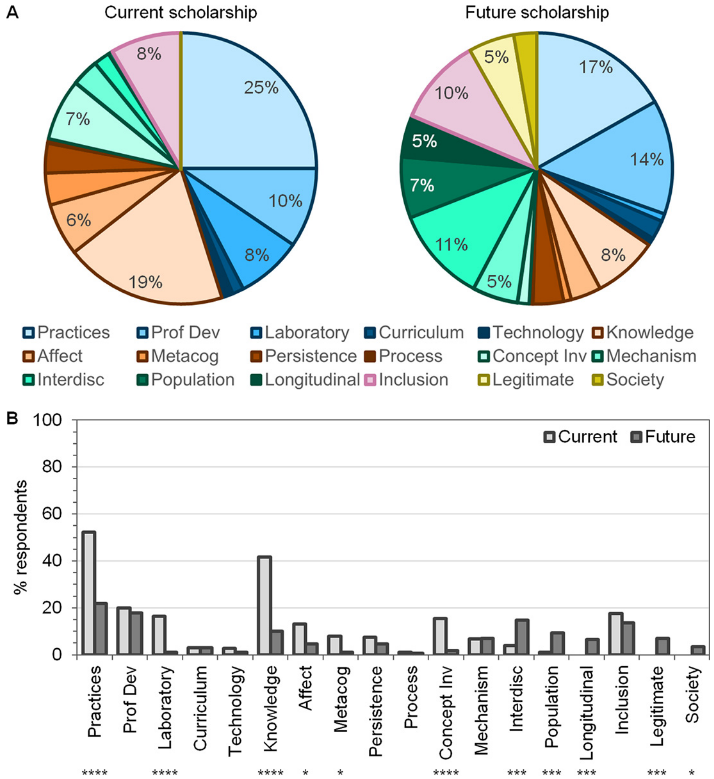

FIG 3. Respondents' perspectives on current and future scholarship in BER. (A) Pie charts showing the percentages of each code from the total number of coded segments for the current scholarship ($n = 368$, coded from 194 total responses) and future scholarship ($n = 220$, coded from 194 total responses) in BER. Each response could be described by more than one code. Codes are grouped into categories by color: classroom interventions (blue), student outcomes (red), research approaches (green), inclusion (purple), and BER impact (yellow). Percentages of <5% are not indicated. The overall distributions of codes between current and future scholarship were statistically different (chi-square, $P < 0.0001$). (B) Bar graph showing the percentage of respondents ($n = 194$) who provided a response identified with each code for current and future scholarship in BER. Responses could be described by more than one code, and the percentages sum up to >100%. Statistical significance between current and future scholarship was determined by the mid-*P* version of McNemar's test for paired binary categorical data. *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; ****, $P < 0.0001$.

various classroom and laboratory settings as well as informal learning environments (28–30). These disciplines thus share overlapping goals and methods, and DBER scholars often have experience in education or social science research (5). However, despite these connections, there remain relatively few interdisciplinary BER papers (1). A recent analysis of the literature found that DBER across STEM disciplines utilize different theoretical frameworks (31), suggesting that BER can both learn from other DBER disciplines and offer our perspectives in interdisciplinary collaborations. We call on the BER community to explore ways to establish greater interdisciplinary connections with other DBER disciplines and echo calls from the past few years for greater collaborations with the learning sciences (28). BER societies, journals, and conferences may wish to explore mechanisms to facilitate these interactions between BER and these BER-related fields to better promote interdisciplinary conversations.

Second, survey respondents also indicated a potential need to expand study populations in BER to include a broader range of students, including community college students. These students are a major group in postsecondary education in the United States: more than 40% of all postsecondary students are enrolled at 2-year institutions, and nearly 50% of all science and engineering degree recipients have attended a community college (32, 33). However, BER studies focusing on community college student populations have been extremely limited (3, 34), a trend also observed in other DBER fields (35, 36). We echo existing calls for further work with community college and transfer students (34, 37, 38), particularly for studies that can bridge BER and other DBER fields. Our survey results indicate that BER could pursue more longitudinal studies that follow students through multiple phases of their education, e.g., transferring from community colleges to universities. Furthermore, community college and transfer student populations tend to encompass more diverse demographics and individuals from minoritized communities (39) such as but not limited to persons excluded by ethnicity and race (40). More evidence-based interventions are needed to support community college and transfer students and to dismantle institutional and systematic barriers (37, 41). We are pleased to see some BER journals recently announce upcoming special issues focusing on community college biology education (42) and urge BER societies, conferences, and journals to facilitate BER work on such understudied student populations. The BER community may wish to reflect on ways to address systematic barriers that may prevent more community college faculty from participating in BER, such as the lack of time, training, financial

TABLE 3
Summary of codes for current and future scholarship in BER

Category	Code[a]	Definition
Classroom interventions	Practices	Develops specific classroom practices to aid in student learning
	Professional development (prof dev)	Equips educators (faculty, graduate students, etc.) to improve their teaching
	Laboratory	Incorporates research into laboratory courses
	Curriculum	Develops resources for others to utilize
	Technology	Focuses on the use of technology in teaching biology and examining its effectiveness
Student outcomes	Knowledge	Assesses student understanding, ranging from specific concepts to the program level
	Affect	Examines student attitudes, motivation, etc., regarding biology learning and instruction
	Metacognition	Fosters student metacognition
	Persistence	Looks at practices to improve persistence of students in biology
	Process	Develops skills related to the scientific method or scientific processes
Research approaches	Concept inventory (concept inv)	Develops instruments to measure student knowledge of concepts
	Mechanism	Investigates the mechanism of why teaching and learning may or may not be effective
	Interdisciplinary	Utilizes frameworks or methodologies from other disciplines to enhance BER
	Population	Focuses on understudied populations, such as community college and transfer students
	Longitudinal	Follows students through multiple phases of their education beyond one course
Inclusion	Inclusion	Makes education more accessible and inclusive to everyone regardless of background
BER impact	Legitimate	Increases general perception of BER as a legitimate or rigorous field of study
	Society	Contributes to biology education aside from that at postsecondary academic institutions

[a]Codes are grouped into larger categories: classroom interventions, student outcomes, research approaches, inclusion, and research impact.

resources, or promotion incentives to support scholarship for community college faculty (34). We argue that future BER scholarship can contribute to these areas of critical importance.

Third, based on the survey results and recent national events, including the Black Lives Matter movement, we call for additional BER scholarship explicitly examining justice, diversity, equity, and inclusion (JDEI) topics to catalyze classroom and institutional transformations in the biological sciences and biology education. While our survey took place before these recent national events, we anticipate that these events only strengthened the desire within the community to see more BER examining such issues. Our work, together with previous studies, demonstrates that there has been relatively little BER on these areas, despite an increasing demand for such work that can provide strategies for improving learning and inclusion for all students. We call on BER societies, conferences, and journals to reflect on ways to better support scholarship in these areas. Some examples include the recent JMBE issue on inclusive science (43) and the current SABER seminar series on striving toward inclusion in academic biology (44). Given similar calls in many other STEM DBER communities (45–47), there may be unique opportunities for interdisciplinary work that merges BER and other STEM DBER fields in studying and advancing JDEI topics in undergraduate education. For example, one of our own campuses, University of California San Diego, has recently announced an interdisciplinary cluster search for 10 to 12 faculty across STEM disciplines whose research, education, and/or service activities are focused on racial and ethnic disparities, especially in relation to the Black diaspora and African American communities (48). Similarly, many other campuses now have chief diversity officers (49, 50) and diversity offices (51, 52). There may be potential for the BER community to engage with members of their campus communities and other similar scholars to advance classroom and institutional transformations to foster inclusion and rightful presence in the biological sciences and biology education (53).

Calls for these changes in the future of BER may reflect the continued development of our emerging and growing field. Further work is needed to gather perspectives from a broader more representative sample of BER practitioners and scholars to continue this conversation. Nonetheless, we hope that this perspective piece will spark introspective discussions within the BER community about how to better facilitate more complex studies and research questions as the field matures. For example, is there a need for additional training for BER practitioners and scholars who wish to tackle longitudinal studies? Are there opportunities to foster collaborations with colleagues at community colleges or in DBER across STEM disciplines? How do we as a community provide support and resources for colleagues who wish to make the transition from life sciences research into BER or add BER scholarship to their existing research programs (54)? As part of the community, we invite fellow BER practitioners and scholars to reflect on how we can collectively and collaboratively continue to promote BER as a field to reach a wider range of educators, researchers, students, administrators, and staff.

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