Broadening Participation in Biology Education Research: A role for affinity groups in promoting social connectivity, self-efficacy, and belonging

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ABSTRACT

Discipline-based education research (DBER) has experienced dramatic growth over recent years, but with growth comes concerns about whether DBER efforts accurately represent the education landscape. By many measures, DBER does not feature a representative range of institutional contexts or a diverse array of voices. Numerous professional development efforts have sought to broaden DBER participation. However, few studies investigate factors that increase engagement by individuals from underrepresented contexts. Drawing on theory related to belonging, self-efficacy, and social learning communities, we investigated persistence in an affinity group aimed at engaging community college faculty (CCF) in biology education research (BER). CCF and CC contexts are dramatically underrepresented in BER in comparison to their central positioning in higher education. We conducted a 4-y study of CCF participants' sense of belonging, self-efficacy, and network connectivity. Our results suggest a relationship between social connectivity, belonging, and persistence in the community, indicating an increase of either of these factors may increase persistence. Self-efficacy increased alongside belonging within the affinity group, which correlated with belonging in BER broadly. These results might inform efforts to engage underrepresented groups of DBER scholars and suggest that such efforts go beyond provision of resources and skills, to focus on building social connections.

INTRODUCTION

Participation and Belonging in Biology Education Research (BER)

Consider, for a moment, the way your interests in education research developed. How did you initially become interested? What factors have played the biggest roles in keeping you engaged in this field to the point of choosing to read this article? What factors do you think might cause other life science educators to be less directly involved in reading or conducting education research?

Engagement in BER has expanded dramatically in recent years. This is reflected in attendance at the annual Society for the Advancement of Biology Education Research (SABER) Meeting growing from an initial group of 29 in 2010 to over 1400 in 2020 (SABER, 2020; Post Meeting Report, 2020; SABER, 2023), and publications in BER journals growing by approximately 40% in recent years (Creech *et al.*, 2022). As with any expanding field or economy, initial stages of growth may happen rapidly, in many directions, and often without being directed by a formal intention or plan for inclusivity. Rapid growth, without consideration of who is joining a community and without formal inclusive structures in place, can result in inequities and lack of inclusion of groups who are critical to the mission of a community (e.g., Sen, 2014,

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Kaur and Arora, 2020). While the growth we have seen over the past decade in BER is exciting and invigorating, it is important that we pause and consider whether our community broadly represents all who stand to benefit from or contribute to biology education and how to best structure our community, and affinity groups within the broader community, to encourage individuals of diverse identities and institutions to belong and persist.

Numerous reports have raised alarms that existing discipline-based education research (DBER) is not representative of the higher education landscape (e.g., Schinske *et al.*, 2017; Lo *et al.*, 2019; Kanim and Cid, 2020, Creech *et al.*, 2022). These papers point out that existing publications showcase an enriched sample of research university contexts with less diverse student populations than seen in higher education more broadly. With the goal of ensuring that DBER findings are relevant and generalizable across contexts (Kanim and Cid, 2020), how can we increase the representation of DBER done at minority serving institutions, community colleges (CC), primarily undergraduate institutions, liberal arts colleges, and other institutional contexts currently underrecognized in the field? As we seek to recruit and support new DBER scholars from those institutions, what factors will be most important to their persistence in the DBER community?

Many professional development (PD) models aimed at encouraging participation in BER emphasize content (e.g., transmitting knowledge and skills, Chang and Pribbenow, 2016) or the need for concrete resources (e.g., access to journals and an Institutional Review Board [IRB], Schinske *et al.*, 2017). However, faculty learning community (FLC) models are increasingly popular in PD, including in supporting faculty efforts in Scholarship of Teaching and Learning (SoTL; Cox, 2003). Such FLC models acknowledge the need to actively attend to community and belonging as a means of enhancing persistence of individuals new to a space or group.

Persistence literature in higher education suggests that a sense of belonging and self-efficacy contribute to an individual remaining engaged in a community (e.g., Graham *et al.*, 2013; Hanauer *et al.*, 2016; Estrada *et al.*, 2019; Hanauer *et al.*, 2022). A sense of belonging (hereafter referred to as "belonging") is sometimes measured through the formation of an identity related to the group (e.g., Estrada *et al.*, 2019). Belonging can be defined as feelings or experiences of mattering, feeling cared about, accepted, respected, or valued by other community members (Strayhorn, 2019). Strayhorn (2019) goes so far as to frame belonging as a basic human need and motivation, which influences human behavior and increases persistence. As Maslow (1954, p. 345) points out in his pyramid model for human needs, after the physiological and safety needs of individuals are met, belongingness needs then emerge. Self-efficacy can be defined as the belief in one's ability to carry out a specific task successfully (Bandura, 1978), such as conducting statistical analyses for a BER project. Both elements can be impacted by the presence of social networks and level of connectivity among group members (Bjorklund *et al.*, 2020). Below we describe each construct and the importance of fostering belonging in the BER community and self-efficacy for BER tasks within an affinity group (i.e., social network).

Impacts of Sense of Belonging on Persistence in a Community

Research in higher education has demonstrated the influence of an individual's belonging in a community on their persistence. For example, biology undergraduate and graduate students who feel they belong to the scientific community and identify as a scientist are more likely to remain in the sciences (Hausmann *et al.*, 2009; Hanauer *et al.*, 2016; Estrada *et al.*, 2019; Kuchynka *et al.*, 2019; Strayhorn, 2019; Hanauer *et al.*, 2022). Social supports are instrumental to fostering such experiences and feelings of belonging, especially for historically underrepresented individuals (Estrada *et al.*, 2019; Strayhorn, 2019) or individuals in contexts where they are inclined to feel *"isolated, alienated, lonely, or invisible"* (Strayhorn, 2019). When studying how social supports contribute to persistence of science postgraduates in biomedical fields, Estrada *et al.* (2019) found that science identity and belonging were significantly related to intentions to persist in the sciences through a biomedical career for both underrepresented and majority students. Such a phenomena can also be seen in initiatives which support faculty pursuing SoTL research (e.g., Cox, 2003; Richlin and Cox, 2004) or teaching PD (TPD; McCourt *et al.*, 2017). If in the present context we hope to support faculty in contributing to and persisting in the BER community, fostering a positive sense of belonging towards this BER community of practice might be essential for persistence.

Impacts of Self-efficacy On Persistence in a Community

A second construct which can predict persistence is self-efficacy. According to Bandura (1997), self-efficacy can be defined as an individual's belief in their ability to carry out a specific task successfully. Higher self-efficacy has been related to higher academic achievement (Komarraju and Nadler, 2013), lower anxiety (England *et al.*, 2017, 2019; Musgrove *et al.*, 2022a), and academic persistence (Torres and Solberg, 2001). Bandura (1997) states there are four different means to build self-efficacy towards a task: 1) mastery experiences (e.g., opportunities to work on a task until completion), 2) vicarious experiences or social modeling (e.g., observing a peer carry out a task successfully), 3) social persuasion (e.g., receiving a vote of confidence from a trusted mentor or peer), and 4) states of physiology (e.g., positive perceptions of our physiological experiences when engaging in a task; Bandura, 1993). Robnett and colleagues (2015) examined the development of science self-efficacy and its relationship between participating in scientific research and science identity (measured through belonging to the scientific community). They suggested that individuals who carried out the research tasks had ample opportunity to increase their science self-efficacy through authentic research involvement, which allowed for mastery experiences, social modeling, and social persuasion. Therefore, by providing similar support to faculty joining the BER community, they may be able to grow in research self-efficacy through opportunities for research involvement.

Relationships between Self-Efficacy and Belonging

Research often discusses reciprocal positive relationships between self-efficacy and belonging. Belonging may contribute to effective self-efficacy development by contributing to a positive affective learning environment which further supports

belonging (Trujillo and Tanner, 2014; Robnett *et al.*, 2015; Skaalvik and Skaalvik, 2019; Bjorklund *et al.*, 2020). When Robnett *et al.* (2015) explored the longitudinal impacts of science self-efficacy and science identity/belonging, they found that an early sense of belonging contributed to self-efficacy development and also that early science self-efficacy predicted heightened identity as a scientist over time. Other work has seen this reciprocal relationship as well; belonging and self-efficacy form a positive feedback loop that contributes to persistence in a domain (Robnett *et al.*, 2015; Skaalvik and Skaalvik, 2019; Bjorklund *et al.*, 2020). Such a pattern is consistent with the cyclical model of science persistence (Graham *et al.*, 2013), which proposed how confidence in science contributes to identification or belonging with science, which then further promotes confidence. This relationship is also seen in teaching communities among preservice teachers, where a sense of belonging to the education program and network centrality was significantly and positively related to self-efficacy beliefs (Bjorklund *et al.*, 2020). Therefore, we predict that providing faculty with opportunities to grow in BER self-efficacy will positively impact both their belonging and persistence in the broader BER community.

Supporting Belonging and Self-Efficacy through Social Learning Communities

Given the importance of belonging and self-efficacy to persistence in a community, how might we best support faculty new to BER in developing their sense of belonging and BER self-efficacy? Lave and Wenger's (1991) legitimate peripheral participation (LPP) theory points to the importance of a network of individuals, known as a *community of practice*, in which newcomers can grow in competence, self-efficacy, and expertise (Lave and Wenger, 1991). Communities of practice are social networks, where relationships and engagement among members within the network can either constrain development or provide opportunities for learning and growth (Borgatti and Ofem, 2010, p. 18). Members of a community of practice are united by a common interest, aim, passion, or concern, and work together to deepen their knowledge of the shared interest or goal through interactions with each other (Wenger *et al.*, 2002). Learning occurs through social participation in shared practices, such as collaboration on research. Novices or "newcomers" to the community engage in tasks which the experts consider "legitimate" or meaningful to the discipline and gradually engage in more complex tasks as their expertise increases. Thus, members move along a continuum from more peripheral to central roles to the community, eventually becoming experts and building self-efficacy primarily via mastery, vicarious experiences, and social persuasion within the network.

The social learning which occurs through communities of practice can support belonging among individuals. Lave and Wenger's (1991) model hinges on the sharing of knowledge between expert, central members and novice, more peripheral members. This dynamic requires the experts and novices to learn from each other and to interact socially. As a result, individuals – regardless of experience level – develop a sense of belonging within the community. Another factor which contributes to an individual's belonging is driven by the shared social identities within the community. When social identities intersect there is potential for increased belonging (Strayhorn, 2019). As Strayhorn indicated, *"social identities such as race/ethnicity, gender, class, sexual orientation, and religion converge and intersect in ways that simultaneously influence sense of belonging."* Thus, bringing together individuals with shared interests *and* underserved identities can create a space where shared interests are explored, and a minority identity becomes a celebrated and valued majority. Such communities of practice where deficit notions of marginalized individuals can be challenged have potential to become *counterspaces* (Solórzano *et al.*, 2000; Ong, Smith, and Ko, 2018) which are smaller communities typically consisting of solely or mainly marginalized individuals that exist within a broader community of practice. Counterspaces serve as safe havens and places of affirmation and support for individuals who share a marginalized identity, which may be based on a visible (e.g., skin color) or invisible (e.g., CC instructor) characteristic (Solórzano *et al.*, 2000; Ong *et al.*, 2018).

The CCBER Context

CCBER is critical to the success of DBER but is presently deeply underrepresented within the field (Schinske *et al.*, 2017; Creech *et al.*, 2022). In the United States, CCs are vital institutions which provide students with accessible, affordable postsecondary education through 2-y degrees (National Academies of Sciences, Engineering, and Medicine [NASEM], 2016). With over 1000 CCs across the U.S., CCs enroll more than 10 million students, serving almost half of all undergraduates (American Association of Community Colleges [AACC], 2022). These institutions serve some of the most diverse populations within higher education, with large proportions of Latina/o, Native American, and Black, low-income, and first-generation students (Twombly and Townsend, 2008; AACC, 2022). Despite the widespread enrollment of students at CCs, these institutions and their students are poorly represented in the BER literature (Schinske *et al.*, 2017; Creech *et al.*, 2022). Such lack of representation could result in decision making within science pedagogy that is not truly informed by the populations who stand to gain the most from it (Kanim and Cid, 2020). To remedy the paucity of CC research, several federally-funded efforts (e.g., *Community College Anatomy and Physiology Education Research Network* [CAPER; National Science Foundation {NSF} #2111119], *Fostering A Community of Scholarship Among Community College STEM Faculty Through Support for Discipline Based Education Research* [CCREST; NSF # 1711693], *Biology Educator/Researcher Cross-Segment Collective* [BERCC; NSF # 1920315], and others) have been created to empower and support community college faculty (CCF) who desire to engage as education researchers.

One such effort is the *Community College Biology Instructor Network to Support Inquiry into Teaching and Education Scholarship* (CC Bio INSITES; NSF# 1730130; also known as INSITES). INSITES is an NSF-funded research coordination network that brings together biology faculty and education researchers from CCs and 4-y institutions to support BER done at CCs by CC faculty (CCF). As further described under *Methods*, INSITES is aimed at engaging faculty in LPP through FLCs to support belonging and self-efficacy development. While an earlier qualitative study elucidated how specific supports received from CC Bio INSTES helped mitigate barriers for CCF to participate in BER (Musgrove *et al.*, 2022b), it is unclear whether participating

in an affinity group contributed broadly to CCF's sense of belonging and self-efficacy (Trujillo and Tanner, 2014). This question is especially pertinent because self-efficacy and belonging generally speaking positively predict persistence in other studies and because our qualitative results (Musgrove *et al.*, 2022b) give rise to uncertainty regarding whether belonging to a smaller, affinity community within the BER community can influence belonging in the broader group. Thus, based on the prior work on belonging and self-efficacy described above, we have generated a hypothetical model of how we might expect connectivity, belonging in INSITES, and self-efficacy to contribute to belonging in BER (Figure 1). This model informs our research questions.

Research Questions

Our work examines models of social learning within the INSITES network to examine the extent to which this community of underrepresented individuals in BER (i.e., CCF) might function to enhance belonging and self-efficacy in BER. Development of a community of practice may be measured via changes in connectivity between individuals in a social network (Cross *et al.*, 2006). Thus, we leverage social network metrics (e.g., connectivity) to predict belonging in an affinity group (i.e., INSITES) and BER self-efficacy. We then examine whether these metrics (i.e., BER self-efficacy and belonging in INSITES) relate to belonging in a larger community that shares the same interest and goals (i.e., the broader BER community). Our motivation in doing this work stems from evidence that belonging and self-efficacy often lead to persistence and further contribution to a community, strengthening the community as a whole (Lave and Wenger, 1991). Thus, our research questions are threefold:

1. To what extent does network connectivity predict sense of belonging and persistence within an affinity group (i.e., INSITES)?
2. To what extent does a sense of belonging within a smaller affinity group predict BER self-efficacy?
3. To what extent does belonging within an affinity group and BER self-efficacy predict a broader sense of belonging in the BER community?

We hypothesize that affinity groups such as CC Bio INSITES may be leveraged to increase an individual's connectivity to other novice or expert members, thereby increasing their belonging and research self-efficacy and ultimately influencing their belonging to a broader community of practice. While the present study is grounded in INSITES as an example of an affinity group engaging an underrepresented group (CCF) in BER and is correlative, not causative, the findings will likely be of value to other constituencies currently underrecognized in education research.

METHODS

This work was determined exempt from IRB review by the CU Boulder IRB (#17-0389).

Positionality

All aspects of the study, including data collection, analysis, and interpretation, were informed by the lived experiences of the research team. One of the first authors (M.M.C.M.), a biology education postdoctoral researcher, identifies as an international, Asian, religious, woman who is the first in her family to go onto pursue higher education. She currently works as a STEM program evaluator and adjunct faculty at a local university. The other first author (M.E.K.), also a biology education researcher, identifies as a bisexual, biracial, Asian woman living with a disability. M.E.K. has served as a nontenured CC instructor and is currently working as a higher education professional at a research-focused institution. M.M.C.M. and M.E.K., joint primary authors, have been trained to use statistics as a tool in biology first, specifically from the ecology and cancer biology disciplines, respectively. The corresponding author L.A.C. identifies as a white woman, holds a strong identity as a biology education researcher, educator, and advocate for CC and transfer students, and is deeply invested in empowering interested fellow faculty from many backgrounds to engage in BER. The second to last author, J.S., identifies as a white man, a CC educator, a biology education researcher, and is also a strong advocate for CC students and faculty. As current (J.S.) and former (L.A.C.) CC instructors, both are passionate advocates for students who attend CCs and strongly believe that CC faculty and students engage in unique and beneficial pedagogical practices, which are often not discussed, may be overlooked, or are not available to members of the BER community. We used our lived experiences and identities to the best of our ability to reduce biases in the way we collected, analyzed, evaluated, and interpreted the data for this research (Intemann, 2009).

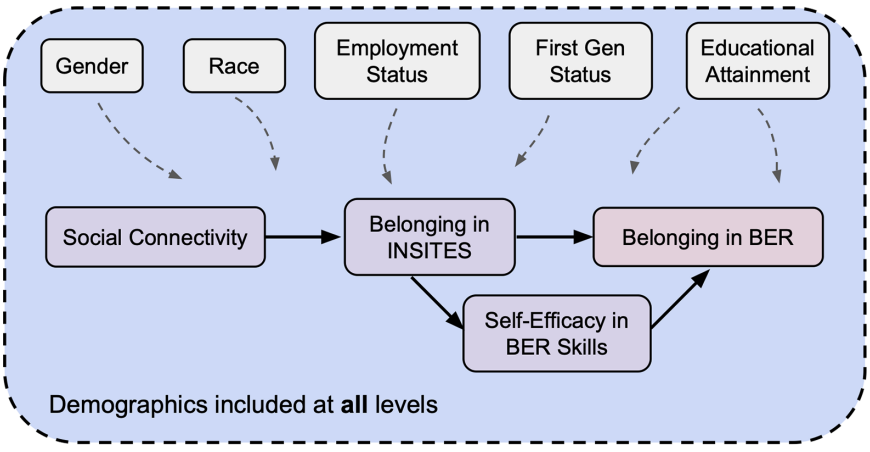

FIGURE 1. Hypothesized relationships between factors which may predict an individual's broader BER belonging, including social connectivity, network belonging, self-efficacy in BER skills, and demographic variables based on prior literature and theory. Solid lines indicate relationships we would predict to contribute to belonging and self-efficacy. Dotted arrows indicate additional factors we would expect to mediate these relationships. Note that while we would expect these relationships to be causal based on prior work, this study is observational and correlative and can only demonstrate relationships between these variables, not causation.

Data collection

Context: The CC Bio INSITES Network. Drawing on established theories of change (Choi, 2011; Corbo *et al.*, 2016) and community based participatory research (Hacker, 2013; Strand *et al.*, 2003), INSITES has taken a community-centered approach to change, specifically considering and incorporating the unique cultures of CCs. CC Bio INSITES aims to empower CCF to ask and investigate their own BER questions, with the goal of building a positive and supportive research community, consisting of both novice and experienced biology education researchers, CC administrators, journal editors, and national BER leaders. The network maintains the explicit goals of increasing the amount of CC BER studies and publications by CCF and providing opportunities for CCF to become leaders within the BER community. To this end, INSITES has offered members intellectual support (e.g., how-to knowledge), resources (e.g., access to journals and an IRB, conference travel funds), and social support. Social support has been characterized by participants as camaraderie, emotional support, validation, and encouragement found when working with like-minded individuals towards a similar goal (Musgrove *et al.*, 2022b).

The INSITES network strived to meet its goals in supporting CCF in pursuing BER through several programmatic components and structures. Throughout 5 y, the network provided continuous support to its participants mainly through: 1) foundational annual meetings which served as the main outlet of PD; 2) a series of PD workshops provided throughout the year; 3) one-on-one support whenever requested, and 4) access to necessary resources for research or access to new opportunities for professional growth. CC Bio INSITES annual meetings were multi-day events focused on the PD of a salient topic in BER (e.g., developing research questions), while also providing participants with opportunities to network, deliberate community building time, and structured work time to advance BER projects (See Supplemental Materials in Musgrove *et al.*, 2022b). Research teams of 3–4 people were established at the initial INSITES annual meeting to promote collaboration, accountability, and provide social support for network members who were new to BER. In year two, analysis mentors to support quantitative and qualitative analysis on members' research projects were invited to attend the annual INSITES meeting and further connect participants with members of the BER community. Many of the mentors formed formal collaborations with research teams. PD workshops offered via Zoom after each annual meeting often aligned with themes identified at the meeting or in response to emerging needs of network members (e.g., incentivized quantitative workshops, or writing, and publication workshops). Throughout the program, INSITES facilitators actively sought to provide network members with access to research resources, such as paid consultation time with analysis mentors or travel funds, and to introduce leadership opportunities that had potential to position INSITES participants in a more central role in the BER community (e.g., grant reviewing, guest editing, serving on conference steering committees). Importantly, a common thread that is emphasized throughout all programmatic components is building community, fostering meaningful interpersonal connections, and providing social support for one another. Websites, publications, and calls for PD programs emphasize mainly content learning goals and provision of resources (e.g., Schinske *et al.*, 2017; Hull *et al.*, 2019, American Society for Microbiology [ASM], 2022). However, in contrast to the emphasis of much work, building community and fostering social support was an explicit learning objective for every part of the INSITES program. Program components, frequency, timing, incentives provided, and a description of each component are provided in the Supplemental Materials in Musgrove *et al.* (2022b).

Because the inception of the network in 2018, CCF members have successfully published or presented their scholarly work with support from CC Bio INSITES. According to our compiled annual reports to the National Science Foundation, six publications have benefited from the support of CC Bio INSITES efforts (e.g., Cotter *et al.*, 2022; Vander Waal Mills *et al.*, 2019; Vemu *et al.*, 2019; Holmberg *et al.*, 2021; Venmu *et al.*, 2022; Alvares *et al.*, 2022) with another two accepted for publication in the coming year and several more in prep. Likewise, CC faculty is occupying more leadership positions (e.g., editorial boards, workshop facilitators) in the broader BER community (Musgrove *et al.*, 2022b). To our knowledge at least nine members of CC Bio INSITES have entered leadership positions because the start of the network in 2018 and six of these members were suggested for or recruited into these positions because of their affiliation with INSITES. These results provide evidence of the impact of CC Bio INSITES in A) increasing representation of CCF published work in BER and B) increasing CCF representation in leadership positions. Notably, despite the apparent productivity of the network, no network members have requested resource support beyond travel, accommodation, and publication costs, yet many report the importance of social and intellectual support (Musgrove *et al.*, 2022b).

Population and recruitment. All CCF network members (N = 55) of the CC Bio INSITES community were emailed presurveys 2 wk before each of four annual meetings (beginning in Spring 2018). CCF members are STEM faculty from CCs participating in network activities which are specifically designed for them. Though the INSITES community includes individuals from funding agencies, and 4-y institutions in addition to CCF, data collection and subsequent analysis are focused on only CCF network members. An average response rate of presurveys was 72% of CCF network members (N = 40). Following the meeting, postsurveys were emailed to network members and open for 2 wk. An average response rate of postsurveys was 58% of CCF network members (N = 32). The broader network community consisted of CCF network members ranging across all levels of BER participation (e.g., some members already published authors in BER and others just beginning), BER mentors from 4-y institutions, and funding agency representatives. A demographic table of network members who participated in this research is available (Table 1).

Survey distribution. Pre- and post-surveys asked participants questions designed both to evaluate the program and to address the research questions listed above. Specifically, they measured a participant's sense of belonging in BER broadly and in the network (INSITES) community, their self-efficacy and experiences participating in BER, access to BER supports, perceptions of different types of support provided from the network and from specific network members, interactions with other

TABLE 1. Demographics of CCF who responded to any of the pre- or post-conference surveys from 2018–2021, including gender, ethnicity, first-generation going to college, employment type, highest degree earned, and those who published in science education before joining the network. We use whether or not network members have a BER publication before joining INSITES as a proxy for BER experience

	N of total network members*	N of members Active in 2021 **(*N* = 35)	N of members Inactive in 2021 **(*N* = 16)
Gender			
Men	8	6	1
Women	43	28	15
Unknown	2	1	0
Race/Ethnicity			
White	38	24	14
Non-White	11	8	2
Unknown	4	3	0
First-generation			
Yes	7	5	2
No	44	29	14
Unknown	2	1	0
Employment type			
Full-time	43	30	12
Part-time	8	4	4
Unknown	2	1	0
Highest degree			
Bachelor's	1	1	0
Master's	18	11	7
Doctorate	31	22	8
Other	1	0	1
Unknown	2	1	0
BER publication before INSITES			
Yes	19	15	4
No	34	20	12

*excluding network mentors and funding representatives.
**two participants are excluded from these calculations given that they joined the network after its inception in 2020, thus the total possible participants is 51 instead of 53.

network members, and professional and personal demographics (for complete survey, please see Supplemental Materials). To address the research questions in this paper, we analyzed network member responses to questions asking participants about their belonging (three questions), their BER self-efficacy (24 questions), their relationships with other network members (a matrix asking about relationships between themselves and other members depending on the year), and demographic information.

Survey instruments. Network measurements. Measurements of connectivity between network members were collected to map the number and type of connections in the network over time. Each participant self-reported who they were connected to (thus drawing an "edge" to another network member). These data are egocentric self-reports from network members, with no further corroboration or filtering of the reported relationships. We argue that such steps to corroborate the relationships are not necessary to this study; instead, the participant's perceptions of their own connectivity, regardless of corroboration by others, are integral to examining their sense of belonging in a community or self-efficacy in participating in BER.

Sense of Belonging. Measures of sense of belonging were adapted from Bollen and Hoyle's (1990) Perceived Cohesion Scale (PCS). Bollen and Hoyle (1990) gathered evidence of validity and reliability for their instrument between two populations: one with high cohesion (sample of undergraduate students at a private liberal arts college in the Northeast U.S.) and low cohesion (sample from a city directory of a mid-sized Northeastern U.S. city). Using chi-square and factor analyses, the instrument's dimensions demonstrated high reliability and validity between the different populations (see Bollen and Hoyle, 1990). With a total of six items, the PCS consists of three items measuring sense of belonging and three items measuring feelings of morale within a community. For our purposes, and as suggested by Bollen and Hoyle (1990), our specific communities of interest (i.e., within the INSITES network and in the broader BER community) were substituted into each question to measure sense of belonging and feelings of morale. For example, one sense of belonging item asks: *"I feel that I am a member of the CC Bio INSITES network",* and an item measuring feelings of morale asks: *"I am happy to be a member of the BER community."* Participants are asked to rate their response to each question on a Likert scale from 1 to 5, with 1 being

Strongly Disagree, 3 being Neither Agree nor Disagree, and 5 being Strongly Agree. Sense of belonging for each participant and each community was calculated as the average score of the first three items of the PCS.

Research self-efficacy. Twenty-four author-generated items asked participants to rate their self-efficacy in their ability to carry out specific tasks related to BER (e.g., collect and analyze data, communicating findings, & designing a study; see Supplemental Materials for complete survey and information on evidence of validity for use with CC instructors). The instrument asks participants to rate self-perceptions of their self-efficacy in participating in BER on a scale of 1 to 5, with 1 being not confident at all, 3 being confident, and 5 being absolutely confident. Two other options were available for participants who were not sure how to rate their confidence, including *"I prefer not to respond"* and *"I don't know."* Self-efficacy in CCF participating in BER was calculated as an average of the self-efficacy subgroups per respondent.

Data analysis

Despite the limited sample size, evidence of validity and reliability were gathered for CCF's measures of sense of belonging within the BER community, sense of belonging within the BER network community, and BER self-efficacy. Validity is a measure of accuracy in drawing correct inferences from survey scores (Reeves and Marbach-Ad, 2016); while reliability measures consistency when a testing procedure is repeated (Knekta *et al.*, 2019). Specifically, we measured content and response process validity through cognitive interviews and internal consistency reliability through calculating Cronbach's alpha scores.

Evidence of validity and reliability for Sense of Belonging. Content validity evidence of sense of belonging items were checked based on expert professional judgment (four CC Biology faculty from outside the INSITES network and another four Biology faculty from 4-y institutions: all active in the BER community) as to the appropriateness of the instrument for the CCF population (Reeves and Marbach-Ad, 2016). Experts examined items and were asked to respond to open ended questions with what the item meant and whether the item was clear. This process confirmed that each item was interpreted as intended by the authors and all items were clear. Due to the repeated measures nature of our data (many same individuals responding to the instrument over several time points), reliability is calculated per each designated time point for each survey population. Across years, internal consistency of the BER belonging subgroups were established with Cronbach's alphas scores ranging from 0.88–0.98, which are considered reliable (Bland and Altman, 1997; see Supplemental Table 1). Given that the validity of this scale had already been examined for multiple other populations across comparable contexts (e.g., Salisbury *et al.*, 2006; Abu Bakar and Sheer, 2013), we did not seek further evidence of its validity.

Evidence of Validity for the BER Self-efficacy Scale. As mentioned, the BER Self-efficacy scale used for this study consisted of a novel set of author-generated questions. In the process of generating these questions, content validity evidence of perception of self-efficacy items were checked based on expert professional judgment (four CC Biology faculty from outside the INSITES network and another four Biology faculty from 4-y institutions: all active in the BER community) as to the appropriateness of the instrument for the CCF population (Reeves and Marbach-Ad, 2016). Experts examined items and were asked to respond to open ended questions with what the item meant and whether the item was clear. This process confirmed that each item was interpreted as intended by the authors and all items were clear (very minor edits were made for clarity). After this step, we conducted cognitive interviews with 11 CC faculty outside of the CC Bio INSITES network to provide evidence of *process response validity* (American Educational Research Association, American Psychological Association, and National Council on Measurement in Education [AERA *et al.*], 2014) of our 24 author-created questions measuring CC faculty's self-efficacy in participating in BER (See Supplemental Materials for further details of how validity evidence was collected). This process provided evidence that our items were highly likely to be interpreted as we intended by our study population.

Demographic and professional demographics. Lastly, the survey collected professional and personal demographic data including self-reported ethnicity, gender, first-generation status, employment status (full or part-time), and highest degree earned (see Table 1 for Demographics). Ethnicity/race was a free response question, which we then converted into white or nonwhite ethnic categories. Individuals who listed identifiers such as "Asian," "Black," and "Hispanic" were grouped as nonwhite. Anyone lacking any of these labels was grouped into White. As a result, anyone who reported a mixed-race identity such as "Asian" and "White" would be placed in the nonwhite group. Individuals who reported having multiracial/cultural identities without listing specific races or ethnicities were treated as NA. Gender was also collected through a free response question which we then converted into two categories (i.e., man and woman) based on given responses. Specifically, all participants used a singular label (e.g., "male," "female," "man") and no participant listed an alternative or a combination of these terms, thus we treated gender in this particular population as a binary variable. First generation status (yes or no), employment status (full-time or part-time), and highest degree earned (Masters or PhD) were all treated as binary variables. Demographic information was processed in R using the tidyverse package (Wickham *et al.*, 2019), and the fastDummies package used to allocate dummy variables (Kaplan, 2020). All survey analyses were conducted in R version 4.1.2. (R Core Team, 2021).

Network analysis. Social networks were constructed as undirected graphs in R using the igraph library (Csardi and Nepusz, 2006) where each person is represented by a node and edges are drawn between persons as long as one individual reported a relationship. Given our incomplete data on the nature and strength of the relationships, edges were drawn as undirected and unweighted. Node degree and various centrality measures (e.g., closeness centrality, betweenness centrality) were then calculated for each individual.

Node degree for an individual is calculated from the total number of edges that include the node in question, that is, the

total number of relationships or connections they were involved in. A person who has a direct relationship with many other people should have a high node degree. *Closeness centrality* is calculated as the sum of the shortest paths between the node and all other nodes, that is, the number of degrees of separation between an individual and everyone else. One might have a high closeness centrality if they are not only connected to many other individuals, but also if they are connected to someone else who is highly connected. *Betweenness centrality* is calculated as the number of shortest paths between any two nodes that pass between the node in question, that is, how many times the individual is part of the chain of the smallest degree of separation between two people. One might have a higher betweenness centrality than expected if they have a relationship with highly connected individuals, even if they themselves are not highly connected. These measures were then associated with each person's ID number for downstream modeling purposes where individual social network features could serve as predictors of belonging.

Mixed Linear Models. To account for the repeated measures of our data, that is, having several responses from the same individual over the 4 y of data collection effort (2018–2021), we employed linear mixed models with individuals as a random effect (i.e., random intercept). To answer our research questions, three mixed linear models were developed to examine what fixed effects were important in predicting each of the following outcome variables: 1) a CCF's sense of belonging to the INSITES network; 2) a CCF's self-efficacy in carrying out BER; and 3) a CCF's sense of belonging to the broader BER community (these models test correlations between the variables in Figure 1, see full linear models for predicted relationships between variables). Mixed linear models were developed using the lmerTest package in R (Table 2; Kuznetsova *et al.*, 2017). All quantitative instruments in our dataset were standardized before modeling. Specifically, we used the scale function in R to center and scale values (i.e., producing z-scores) to facilitate comparisons between the effects of predictors with different orders of magnitude. Models were checked using the performance package in R (Lüdecke *et al.*, 2021) for assumptions such as predictor collinearity and normality of the residuals. Notably, while these models are set up to test the relationships between predictors and outcomes, we did not carry out a randomized or quasiexperimental design. Thus, the outcomes of the models can be interpreted as correlational. The three linear mixed models developed, and variables kept in each are as follows:

Model 1:
INSITES Belonging ~ Node Degree + Betweenness Centrality + Closeness Centrality + Race + First Generation + Full-time + Doctorate + Gender + Time + (1 | ID)

Model 2:
BER Self-efficacy ~ INSITES Belonging + Race + First Generation + Full-Time + Doctorate + Gender + Time + (1 | ID)

Model 3:
BER Belonging ~ INSITES Belonging + BER Self-efficacy + Race + First Generation + Full-time + Doctorate + Gender + Time + (1 | ID)

We calculated the conditional R^2 using the r.squaredGLMM function from the MuMIn package in R, which describes the variance explained by the model considering both the fixed and random effects (Nakagawa *et al.*, 2017). Standardized coefficients for each coefficient and their *p* values were also calculated for each model. Fixed effects variables with higher standardized coefficients within a given model indicate a greater effect size, and thus explain a greater proportion of variance in the response variable. A positive coefficient implies a positively correlated relationship while a negative coefficient indicates an inverse relationship. A coefficient of zero implies no relationship, that is, knowing the value of the predictor does not help to guess the value of the outcome variable. While the exact values of standardized coefficients are scaled such that they do not easily describe the effect size of the original variable (e.g., increasing numbers of connections from five to six increases sense of belonging from 4.0 to 4.2), standardized coefficients allow for more accurate comparison of the effects between variables with differing scales.

Our initial model (Model 1, predicting INSITES belonging from connectivity, demographics, and time) failed the test of collinearity. Thus, for this model to predict belonging in the

TABLE 2. Framework of the linear mixed models developed to understand a CCF's self-efficacy, and sense of belonging in the network and broader BER community

Variable Name	Model 1	Model 2	Model 3
Participant ID	Random Effect	Random Effect	Random Effect
Time (each year pre/post meeting)	Fixed Effect	Fixed Effect	Fixed Effect
Gender Man or Woman	Fixed Effect	Fixed Effect	Fixed Effect
Race White or Non-White	Fixed Effect	Fixed Effect	Fixed Effect
First Generation True or False	Fixed Effect	Fixed Effect	Fixed Effect
Doctorate True or False	Fixed Effect	Fixed Effect	Fixed Effect
Full-time Status True or False	Fixed Effect	Fixed Effect	Fixed Effect
Node Degree z-scored	Fixed Effect	–	–
Betweenness Centrality z-scored	Fixed Effect	–	–
Closeness Centrality z-scored	Fixed Effect	–	–
INSITES Belonging z-scored	Outcome	Fixed Effect	Fixed Effect
BER Belonging z-scored	–	–	Outcome
BER Self-efficacy z-scored	–	Outcome	Fixed Effect

–= not included in this model.

INSITES community, we also trained linear mixed models using lasso, that is, L1 penalization of the regression coefficients, using the glmmLasso package in R. This approach has been shown to be more tolerant of collinear variables included as predictors by penalizing inflated coefficient values. The value for lambda, that is, the specific penalty of this lasso model, was calculated using fivefold cross-validation model to find the lowest penalty value with comparable errors/performance according to root-mean squared error and Akaike Information Criterion statistics.

Comparison of Active versus Inactive members of CC Bio INSITES Network. To further address research question one and examine whether network connectivity impacts persistence and activity level of participants within an affinity group, we also conducted logistic regression to identify significant predictors of ongoing retention and engagement in the cohort. This model used an individual's connectivity at an earlier time point (i.e., 2018 postannual meeting) to predict whether they would be active or inactive in the network at a later time point (i.e., 2021), while controlling for other demographic features of the participant. Active status of network members was designated for participants who attended the annual network meeting and/or the network's PD workshops throughout the given year (e.g., statistical analysis and writing workshops that were held in remote and both synchronous and asynchronous formats). To determine whether there were any significant differences in connectivity between active and inactive members of the network participants per year, Kruskal-Wallis rank sum tests were also conducted.

Methodological Limitations. Our findings are constrained by four main factors: 1) the limitations to run sophisticated reliability and validity tests due to sample size, 2) the potential impact of the COVID-19 pandemic on our measured variables and response rate, 3) the measure of quantity, not quality of relationships in the network, and 4) the correlational nature of our findings. First, because we are drawing from an already small population pool (i.e., CCF conducting research), our sample size did not allow the statistical power to run factor analysis or confirm factors for our measures. However, we have used other techniques (e.g., cognitive interviews) to collect evidence of response process validity, content validity, and internal consistency reliability. In conducting social network analysis, missing responses can affect our ability to fully capture existing relationships between participants. As such, it is possible that our reported metrics (e.g., degree, centrality) are underestimated for our participants. Secondly, data was collected longitudinally from 2018 to 2021, before and during the COVID-19 pandemic. Because response rates dropped predictably as we entered into the pandemic, our longitudinal sampling may be from individuals who had more opportunity and/or motivation to respond during the pandemic or were not limited by pandemic-related occurrences. Third, within the network analysis, quality of relationships was not accounted for in the model or data collection effort. It is possible that having fewer, richer quality connections to individuals within a community may be just as impactful to a CCF's sense of belonging as having several connections. Finally, our models can test the relationships between predictors and outcomes, but because we did not carry out a randomized or quasiexperimental design, our outcomes can only be interpreted as correlational and not causal. Future research on CCF using network analysis should consider capturing the strength and quality of relationships and should strive to demonstrate causality if possible.

RESULTS

Of the 55 network members, a total of 53 unique network members participated in at least one of the seven surveys (three pre- and four postsurveys) from 2018–2021. Due to the size and nature of our data, no individual participants were removed from the analysis. Instead, our models only included participant responses that had all of the specified variables available. After calculating our survey constructs and node measurements, our dataset contained 212 complete survey responses and 215 partially complete survey responses. Of the 53 unique participants who replied to at least one survey, the average number of times that a participant completed the survey was 4.33. Number of responses per participant ranged from one to seven. As expected with typical program attrition and the effects of the global pandemic, the number of individual responses at each time point peaked at 39 responses in 2019 and had dropped to its lowest level of 14 responses in 2021. Participants were mostly women (81%), white (72%), and employed full time (81%). Fourteen percent were first generation. In addition, and in order to ensure that the faculty who participated in our study were representative of the complete spectrum of BER experience present in the group (i.e., entering with prior experience vs. entering having never done BER), we explored who entered the network with a prior BER publication versus who had not. Sixty-four percent (34 of 53) of the members who participated in our study did not have a BER publication before joining the CC Bio INSITES network (Table 1).

Research Question 1: To what extent does network connectivity predict sense of belonging and persistence within an affinity group (i.e., INSITES)?

RQ1 Finding 1: Sense of belonging in the CC Bio INSITES community correlated with the node degrees of connections and time. After running Model 1 to address this question, standardized coefficients revealed that CCF with more connections to other CCFs had a higher sense of belonging within the network (see Supplemental Figure 2). Also, CCF had a greater sense of belonging over the time in the program. However, multicollinearity metrics variance inflation factors indicated there was high collinearity between the time and social network variables. We attempted to address this collinearity in order to better interpret our data (see Supplemental Materials, Mixed Linear Model of INSITES Belonging), however we concluded that our data set at present does not allow training and interpretation of a linear mixed model to address this initial research question (we included these results in the Supplement for those interested). Thus, in pivoting to use descriptive statistics and visualization (Figure 2), we see that generally higher numbers of connections positively correlate with higher sense of belonging at all later time points. The significance of these weak correlations is such that we cannot say that connectivity causes increased belonging, but the two features are related within our population. Notably, a high degree of endorsement of the maximum INSITES belonging score across all time points (between

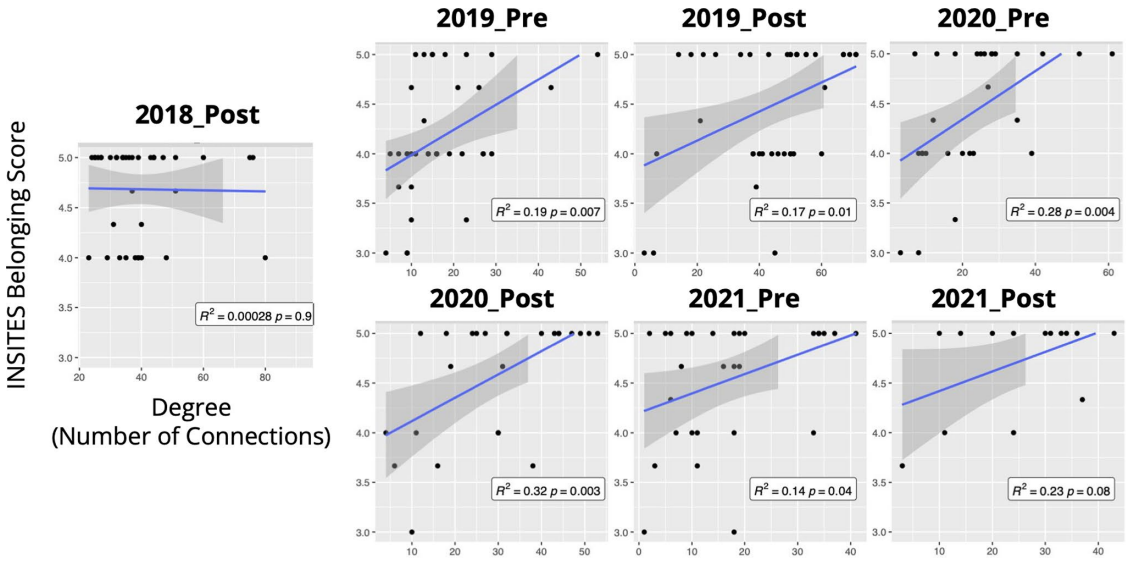

FIGURE 2. Correlations between the degree of connectivity and INSITES sense of belonging among CCF at each survey time point (2018–2021). Many correlations indicate a significant, positive correlation between connectivity and belonging.

TABLE 3. Coefficients for included predictors of CC Bio INSITES network activity status in 2021 and their significance as revealed by a logistic regression model.

Predictor	Coefficient	Significance
Network Degree	1.1921	°
Gender Identity Woman	–1.5359	
First Generation Status	1.1542	
Full-time Employment	1.9263	°
Racial/Ethnic Identity White	–0.3133	
Doctorate Degree	0.5087	

Significance denoted by model calculated p value where * = p value < 0.05, ° = p value < 0.1, and lack of a symbol represents p value > 0.1.

25 and 71% or participants) and across many different degrees of connection (i.e., a celling effect) may have weakened the correlations and decreased the ability to detect relationships between these two variables. Thus, the detection of the correlations here, even considering the potential of a celling effect, provides evidence of a relationship between these two variables.

RQ1 Finding 2: Connectivity within INSITES and full-time instructor status correlated with activity in the network community. Using CCF activity status data from 2021, logistic regressions revealed that network members' node degree connectivity and employment status most strongly correlated with activity status (i.e., persistence as active members) throughout the network's lifespan (Table 3, Figure 3, AUC = 0.7607). Though only marginally statistically significant, this correlation could suggest that the more connections a full-time CCF had, the more likely they remain an active network member by 2021 (i.e., during the second year of the pandemic when participation was at its lowest point). In each year, pre- and post-survey data depict active members having greater connections, some statistically significant, compared with inactive members (Figure 4).

Research Question 2: To what extent does a sense of belonging within a smaller affinity group predict BER self-efficacy?

RQ2 Finding 1: A CCF's BER self-efficacy is related to their sense of belonging in the INSITES network, gender, and time. Standardized coefficients reveal that CCF with lower INSITES sense of belonging, and who identify as women, have lower self-efficacy in participating in BER (Table 4; Figure 5). CCF also seem to have lower self-efficacy at earlier time points, often before the annual network PD meetings, as seen in the coefficients for pre-survey time points. High positive effect sizes were seen with the highest degree earned, indicating the more education CCF earned, the greater BER self-efficacy, though it was not statistically significant. Conditional R^2 reveals that 82%

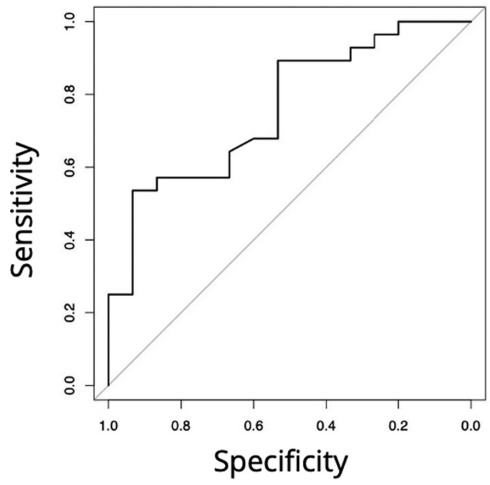

FIGURE 3. Receiver operating characteristic (ROC) curve showing sensitivity and specificity of the logistic regression model for varying cut-off values. The area under the curve (AUC) is calculated and represents the overall performance of the model.

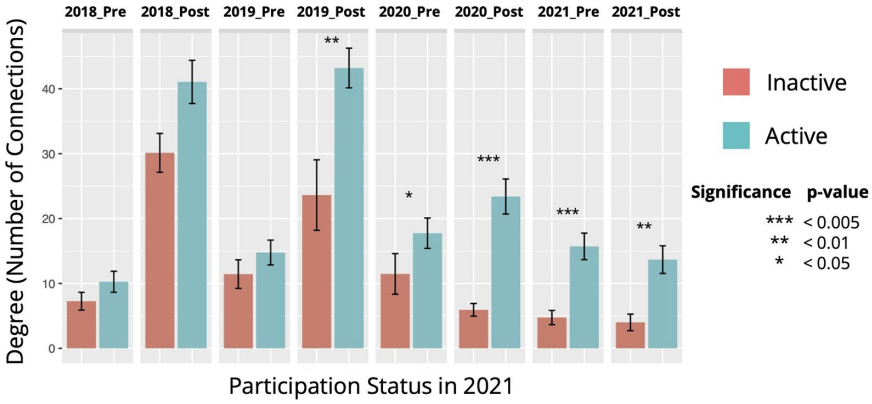

FIGURE 4. Bar graph comparing network members who were active or inactive in the network activities by 2021 against degree of connectivity. The more connected members were more likely to remain active over time. Significance was determined via Kruskal-Wallis rank sum test within each time point given the nonnormal distribution of degree across our sample.

of variation in BER self-efficacy was explained by the model predictors. Notably, similar to in RQ1, a high degree of endorsement of the maximum INSITES belonging (i.e., a celling effect) may have weakened the correlations and decreased the effect of INSITES belonging on BER Self-Efficacy.

Research Question 3: To what extent does belonging within an affinity group and BER self-efficacy predict a broader sense of belonging in the BER community?

RQ3 Finding 1: A CCF's sense of belonging to the broader BER community is related to their sense of belonging in the INSITES network and their BER self-efficacy. Standardized coefficients revealed the relationship between variables–higher INSITES belonging and higher BER self-efficacy correlate with higher belonging within the BER community (Table 5; Figure 6). Though other variables such as CCF demographics and time were not statistically significant, first-generation status had high negative effect sizes, indicating that individuals who identified as first-generation had a lower sense of belonging in the BER community compared with non–first-generation CCF. Conditional R^2 reveals that this model explains 62% of variation in BER sense of belonging within this sample population.

TABLE 4. Coefficients for included predictors of BER self-efficacy and their significance as revealed by a linear mixed model

Predictor	Coefficient	Significance
(Intercept)	0.5821	
INSITES Belonging Score	0.1903	***
Racial/Ethnic Identity White	–0.0210	
First Generation Status	–0.1037	
Full-time Employment	0.1337	
Doctorate Degree	0.3274	
Gender Identity Woman	–0.9425	*
Time 2019 Pre Meeting	–0.2576	*
Time 2019 Post Meeting	0.1075	
Time 2020 Pre Meeting	0.0024	
Time 2020 Post Meeting	0.0630	
Time 2021 Pre Meeting	–0.2604	*
Time 2021 Post Meeting	0.0613	

Significance denoted by model calculated p value where *** = p value < 0.005, ** = p value < 0.01, * = p value < 0.05, and lack of a symbol represents p value > 0.05.

DISCUSSION

This study contributes to the literature on belonging, self-efficacy, and persistence by extending existing theory to individuals entering into DBER, particularly those from underrepresented groups (e.g., CCF). We used the context of a BER PD network to investigate connections between belonging, self-efficacy, network connectivity, and persistence. Our findings suggest that existing theory can inform PD, outreach, and community building within DBER. Below we describe the ways our findings intersect with existing literature on belonging, self-efficacy, and persistence, and discuss implications for future efforts aimed at engaging faculty in DBER.

For individuals entering BER, connectivity may influence a sense of belonging, which in-turn relates to persistence in the community

Building a social network primarily entails fostering the formation of new social connections among individuals. These connections can then afford network members with a variety of supports, such as development of cultural knowledge, relationships that provide friendship and afford connections to others who may be more central to the community, camaraderie and solidarity in difficult endeavors, and a sense of membership or belonging to a group (Bourdieu, 1986; Portes, 1998). Furthermore, as described above, communities of practice theory suggests that the number of connections one has grows as one moves into more central locations within a community. Members who are central to a community can then both receive and offer more benefits to other community members (Lave and Wenger, 1991; Wenger *et al.*, 2002). These actions, both providing and receiving support, in addition to being increasingly recognized as holding expertise, can increase belonging for instructors participating in PD (Looi *et al.*, 2008) even when conducted primarily online (Khalid and Strange, 2016). This can be especially impactful for individuals who identify with minoritized groups, when the communities of practice consist of others sharing in their identity (Ong *et al.*, 2018).

It is this research and theory that led us to predict that INSITES members who experienced a greater degree of network connectivity might experience a greater degree of belonging and persist as active members in the network over time. Evidence collected surrounding INSITES largely aligns with our predictions. Our first predictive model that examined the influence of connectivity, time, and demographics on INSITES community belonging exhibited high multicollinearity, especially between time and connectivity, which indicate that this model may not accurately capture the effects of each

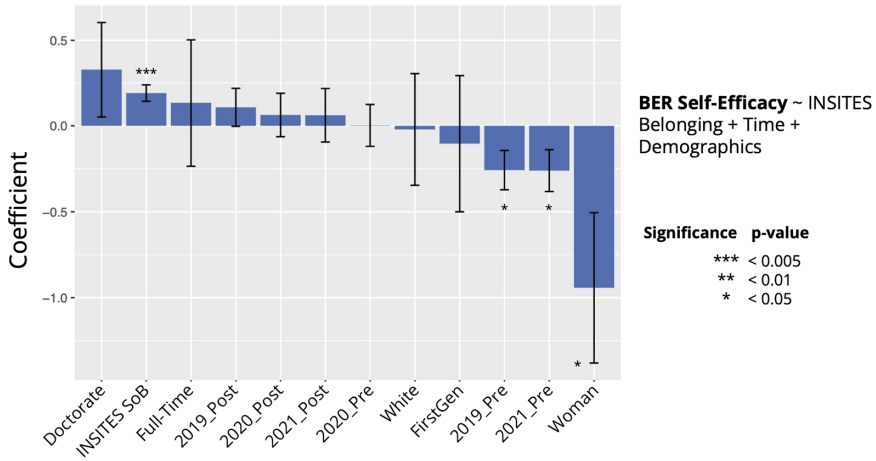

FIGURE 5. Mixed linear model predicting the variation in a CCF's self-efficacy in participating in BER. The most important fixed effects included a CCF's INSITES sense of belonging, gender, and time. Multiple responses by participants over time were accounted for as the random effect. The full model was: BER Self-efficacy ~ INSITES Belonging + Race + First Generation + Full-Time + Doctorate + Gender + Time

predictor. This is not unexpected given that we expect connections within a network to increase with time. However, it precludes us from being able to parse the effects of time in the community versus the number of connections on belonging. Nonetheless, our data suggest that relationships between connectivity and belonging may exist *within* timepoints (Figure 4). Our second analysis more definitively demonstrated that having more connections influenced INSITES CCF's likelihood of remaining active in the network (i.e., persisting).

Together, the above evidence aligns with our expectations based on social capital theory (Bourdieu, 1986) and communities of practice (Lave and Wenger, 1991). When social networks grow over time, define shared norms and espouse common beliefs, more connections are made, and services associated with gaining social capital increase (Adler and Kwon, 2009). Within INSITES, we expect that several services resulting from network connectivity were directly related to increased persistence within the community. For example, social supports and particularly encouragement and validation contributed to feelings that CCF's work and participation in the network were "worthwhile" (Musgrove *et al.*, 2022b). Likewise, many aspects of social capital formation within INSITES may have influenced belonging; our qualitative data suggest that formation of camaraderie and solidarity in doing BER directly increased belonging. Receiving intellectual supports via network connections helped members to build skills, thereby increasing CCF's self-efficacy, which in turn helped some members to feel they had agency to become "changemakers" within the affinity group and beyond (Musgrove *et al.*, 2022b). In addition, belonging can be increased by an increasing number of connections within a community because more connections contribute to a sense of group affiliation and social/group identity formation (Adler and Kwon, 2009). We see this mentioned in our qualitative data when members describe that having more connections increased their comfort and sense of having a "buddy" or others with whom they could relate at larger conferences (Musgrove *et al.*, 2022b). Within the data presented here, even the existence of a collinear relationship between time and connectivity, support that these processes are occurring within INSITES over time. Given that CCF represent a group that has historically been marginalized and underrepresented within the broader BER community, these results are promising. It is also both intriguing and promising that we did *not* see significant relationships among belonging and the demographic factors we tested (race, gender/ethnicity, first generation status). We are cautious in interpreting this finding given the small sample size, increased potential for sampling bias, and narrow context of the study. However, it is possible that effects of demographics on belonging may have, in part, been moderated by the context of the INSITES group, which held other identities in common. This is not dissimilar to other research on counterspaces and affinity groups (Ong *et al.*, 2018; Solórzano *et al.*, 2000). It may be possible to extend the findings from INSITES, including programmatic approaches to building connections and belonging, to other marginalized research groups within DBER in order to increase persistence and belonging within affinity groups.

TABLE 5. Coefficients for included predictors of BER sense of belonging and their significance as revealed by a linear mixed model

Predictor	Coefficient	Significance
(Intercept)	0.1730	
INSITES Belonging Score	0.2836	***
Racial/Ethnic Identity White	–0.2452	
First Generation Status	–0.4067	
Full-time Employment	–0.0436	
Doctorate Degree	–0.0519	
Gender Identity Woman	0.0885	
BER Self-efficacy	0.2653	***
Time 2019 Pre Meeting	0.1423	
Time 2019 Post Meeting	0.1676	
Time 2020 Pre Meeting	–0.1060	
Time 2020 Post Meeting	–0.0141	
Time 2021 Pre Meeting	–0.2279	
Time 2021 Post Meeting	0.1037	

Significance denoted by model calculated p value where *** = p value < 0.005, ** = p value < 0.01, * = p value < 0.05, and lack of a symbol represents p value > 0.05.

For individuals entering BER, self-efficacy increases alongside a sense of belonging

Our study contributes to an existing body of research that connects an individual's sense of belonging to self-efficacy (Trujillo and Tanner, 2014; Robnett *et al.*, 2015; Skaalvik and Skaalvik, 2019; Bjorklund *et al.*, 2020). Self-efficacy is critical in that it correlates with numerous positive outcomes in terms of

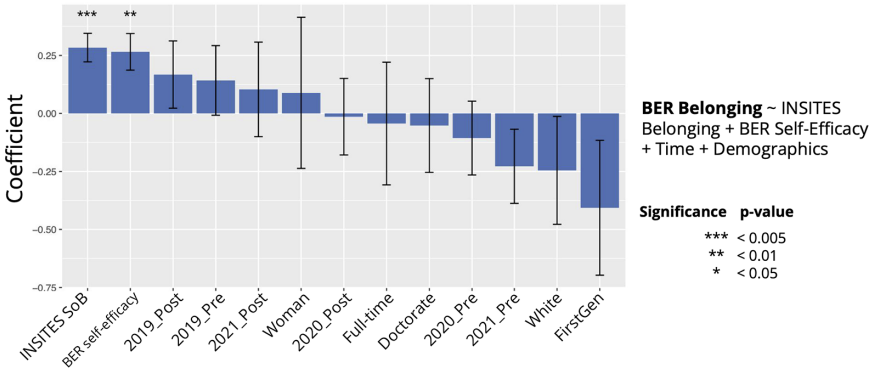

FIGURE 6. Mixed linear model predicting the variation in a CCF's sense of belonging to the broader BER community. The most important fixed effects included INSITES sense of belonging and BER self-efficacy. Multiple responses by participants over time were accounted for as the random effect. The full model was: BER Belonging ~ INSITES Belonging + BER Self-efficacy + Race + First Generation + Full-time + Doctorate + Gender + Time

achievement and persistence in a community (e.g., Komarraju and Nadler, 2013; England *et al.*, 2017; Torres and Solberg, 2001; Musgrove *et al.*, 2022a). We therefore found it encouraging to observe heightened self-efficacy as participants' sense of belonging increased over time, and as explained in the section above, this was corroborated by our qualitative results (Musgrove *et al.*, 2022a). Building off our other findings, these results suggest that a focus on building a sense of belonging alongside supporting self-efficacy might yield positive outcomes for new populations of individuals entering DBER.

Our results further aligned with prior research in suggesting that women tend to report lower self-efficacy than men in science (Williams and George-Jackson, 2014, Sterling *et al.*, 2020). This finding might seem surprising in that women far outnumber men in BER (>75% of attendance at the SABER 2020 meeting was women, SABER, 2020). As such, women would seem to have many opportunities to see other women succeeding and belonging in BER, increasing their likelihood of building self-efficacy through vicarious experiences (Usher and Pajares, 2008). Likewise, we might expect that being persuaded of one's efficacy by others who share social or gender identities might also further increase self-efficacy (Usher and Pajares, 2008), however we see no evidence that this is the case. Instead, we observe common patterns: that women tend to feel less efficacious than men in technical, math-heavy, or STEM-related fields. There is no evidence for a mollifying effect of being in an environment with majority women.

For individuals entering BER, meaningful participation in an affinity group might lead to broader belonging in the field

Prior research has shown that membership to smaller groups within a community can boost overall sense of belonging within a broader community, or at the very least, help marginalized individuals to maintain a sense of self-worth within a community even when dominant narratives promote a deficit view of their membership. For example, identifying with a special interest group, in which participants hold a more specific interest related to a broader group's goals, can help participants to feel belonging to the broader group because they recognize a common interest (Davis *et al.*, 2017; Tori and Morley, 2011). Similarly, in research on PD of CC faculty, there is evidence that connecting with small groups or individuals who share professional experiences or are at a similar state in their PD can increase belonging (Diegel, 2013; Edwards *et al.*, 2015; Corwin *et al.*, 2019). Marginalized individuals who hold identities in common may find that they experience greater acceptance and lower stereotype threat within *counterspaces* that are dominated by and held primarily for individuals of their identity (Ong *et al.*, 2018; Solórzano *et al.*, 2000, Case and Hunter, 2012). These spaces may be especially important when a field is not diverse or when there has been a history of exclusion of individuals holding certain identities.

Despite many positive outcomes of these groups, individuals in affinity groups or who are members of counterspaces may express that they feel greater belonging with the small group, and less with the broader community, especially when they perceive acceptance of their interests or identities to be lower within the broader community than within their group (Solórzano *et al.*, 2000; Case and Hunter, 2012; Ong *et al.*, 2018). This aligns with prior findings from the INSITES community. In interviews conducted among INSITES members, several expressed that, though they feel belonging to INSITES specifically, this did not always extend to feeling a greater sense of belonging to the broader CC BER community (Musgrove *et al.*, 2022b). They also expressed, in alignment with findings from the counterspace literature (Case and Hunter, 2012), that INSITES provided them with affirmation of their worth or contributions while the broader community did not. Many felt "out of place" at events for the broader community while conversely they shared a sense of being "in it together" when they were at events for the smaller affinity groups (Musgrove *et al.*, 2022b).

While the above evidence suggests that belonging in the INSITES affinity group might not confer belonging in BER more broadly, the present study uncovered a positive correlation between belonging to INSITES and belonging to the broader BER community (Table 5; Figures 6 and 7C). Taken together, these findings raise questions regarding the extent to which affinity groups generate belonging and engagement in larger communities and the mechanisms leading to a sense of belonging for individuals within different parts of a community. Future studies should investigate whether individuals simultaneously gain a sense of belonging in a broader community when engaged in an affinity community (Figure 7A), or whether members of an affinity community overlap with the broader community, but to a considerable extent continue to feel low or no belonging to the broader community (Figure 7B). If the latter is the case, then affinity groups – even when they are affiliated with a broader community – may include members that do and do *not* identify with the broader community. The degree of community overlap may be related to the degree of connections individuals in the affinity group have within both communities and their sense of acceptance and value within the broader community

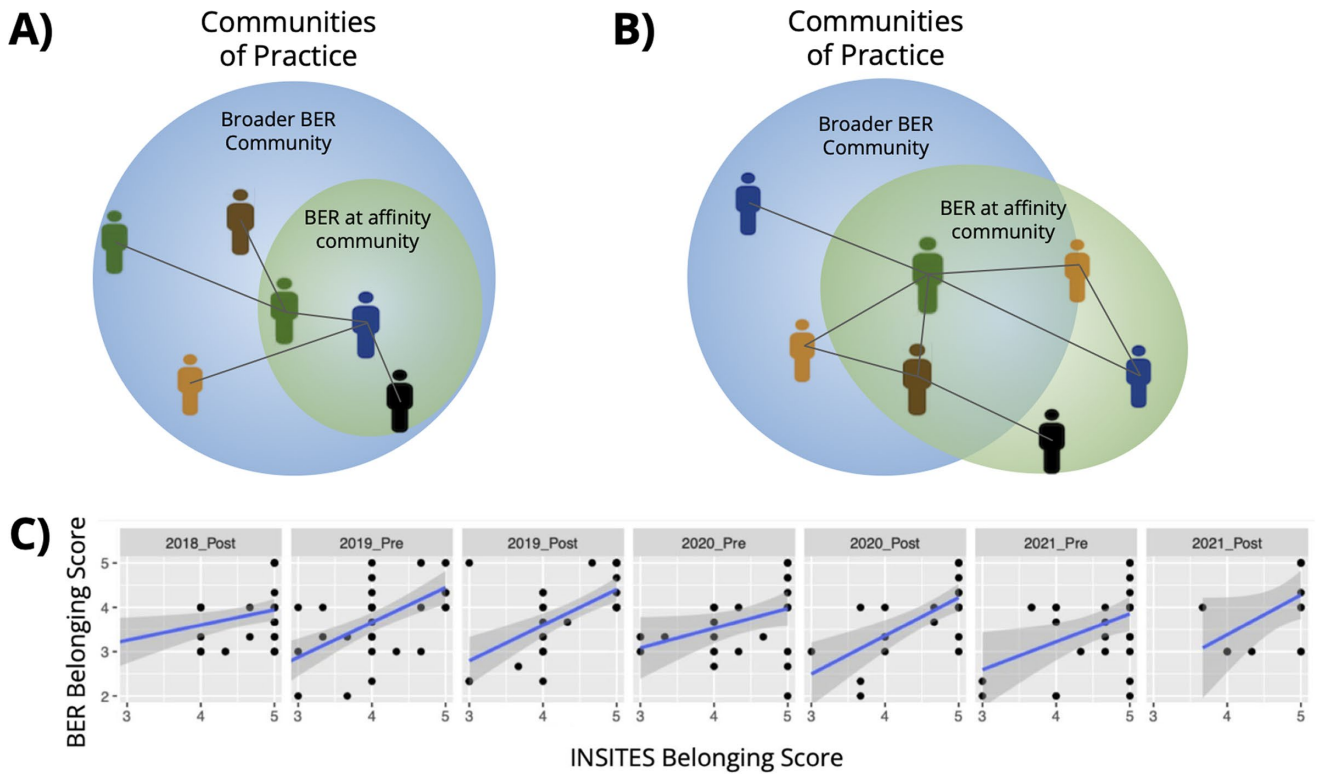

FIGURE 7. Two potential models depicting how communities of practice between the broader BER community and an affinity group might relate. Model A assumes the affinity group community of practice is situated completely within the broader community, where individuals who may be central to the broader BER community may also be highly connected to those in the affinity group, often leading to a greater sense of belonging to both communities. Model B depicts the affinity group community of practice as one where there is *some* overlap with the broader community of practice. In this model, individuals can be central to both or central to one community and peripheral to another but may also occupy distinct spaces just within the affinity group. Panel C demonstrates that higher levels of INSITES belonging predicted broader BER belonging, but that some individuals felt a higher sense of belonging in one community and not the other.

(Musgrove *et al.*, 2022a). Additional studies have the potential to clarify how network structure and affinity group sense of belonging influences broader belonging within a professional group or society and ultimately persistence. While BER affinity groups likely contribute to belonging with BER broadly, more can and should be done to include individuals who are underrepresented and marginalized within the BER community in the broader community.

More can likely be done to increase BER belonging at multiple levels, within affinity groups and beyond. For example, work on affinity groups within companies suggests that formal recognition and provision of resources to the affinity group by the organization may help affinity members feel recognized and valued broadly (Van Aken *et al.*, 1994). In addition, individuals in an affinity group who have opportunities to work to solve problems and specific issues within the organization, identify training needs, or work to provide emotional support for their members may 1) feel a greater sense of contributing to the broader group, and 2) have opportunities to improve the overall organization structure in ways that benefit their group. However, belonging and self-worth of group members is only supported *if the broader organization responds to and acts upon their efforts* (Van *et al.*, 1994; Pour-Khorshid, 2018). Research on counterspaces suggests that groups or spaces where the majority of interacting members are individuals with underserved identities are important for those individuals' safety, socioemotional support, maintenance of self-worth, and overall well-being (Case and Hunter, 2012). Theorists suggest that these groups are most effective at promoting well-being and maintaining belonging when there are opportunities for members of that group to actively resist deficit narratives about their underserved identities that are espoused by the dominant cultures within an organization (Case and Hunter, 2012). Some research goes so far as to say that these spaces should consist solely of underserved individuals to support this purpose (Solórzano *et al.*, 2000). However, other research has recognized the value of including participants who do not identify with the predominant underserved identities in the group (Ong *et al.*, 2018). Alternatively, rather than relying solely on individuals of a certain demographic to advocate for themselves, organizations might support affinity groups consisting primarily of members with majority identities who strive to address issues of underrepresentation and equity across the organization (e.g., by acting to promote anti-racism; Blitz and Kohl, 2012). Overall, the research on both affinity groups and counterspaces suggest that organizations may be most successful in supporting underserved members by creating multiple and varied groups, structures, and spaces that members can elect to participate in. By creating diverse structures of support and diverse affinity groups within a broader

group, we may be able to increase inclusion across a professional community and strengthen belonging for individuals from a variety of backgrounds.

BER networks and PD efforts might wish to feature sense of belonging, social connectivity, and self-efficacy in their listed goals and meeting agendas

Many undergraduate science courses have a reputation for content overload and a fast pace, which has driven some students out of science (Seymour and Hewitt, 1997). Efforts to reform such courses have often urged closer attention not just to content learning, but to students' sense of belonging and self-efficacy (Trujillo and Tanner, 2014). Could we be nearing a similar reckoning in programs that engage new individuals in DBER? Many efforts, including some of our own, have emphasized the transmission of knowledge and access to resources to allow new individuals to engage in BER (e.g., Schinske *et al.*, 2017; Hyson *et al.*, 2021; Miller and Higbee, 2021; ASM, 2022).

In contrast, the INSITES network prominently featured social connectivity and belonging as central programmatic goals, with substantial time specifically devoted to supporting connections and belonging (Musgrove *et al.*, 2022a). While opportunities to learn BER skills and to gain access to resources were valued by participants, social support was found to be especially critical (Musgrove *et al.*, 2022a). In the present study, we did not directly compare the importance of content learning versus access to resources versus social support for participants, but we did uncover evidence that sense of belonging and social connectivity might be important for persistence in BER. Further, we have indirect evidence that some commonly requested resources for CC BER might be less important than expected. For example, a lack of access to an IRB is one of the most commonly cited barriers to doing BER at CC's (Schinske *et al.*, 2017). As a result, we made arrangements for IRB access for all INSITES participants. However, in spite of the productivity of INSITES participants in conducting BER (see above), not a single INSITES participant requested support with IRB access.

This raises numerous questions worthy of further investigation. At what point and to what extent during DBER PD programs should research skill development be emphasized? Might an overemphasis on acquiring BER skills drive otherwise capable individuals away from DBER, much in the same way that content overload filters some students out of the sciences (Seymour and Hewitt, 1997)? Is it possible that belonging and social connectivity are the main, or even the *only*, prerequisites to engaging in BER, with resources and skill development stemming from social connections? Further investigation into the preeminence and importance of social supports in contributing to new scholars' entrance into the BER community is warranted.

In light of these findings, we encourage researchers and professional developers to consider the role of affinity groups, such as INSITES, in nurturing social connections and belonging within the broader BER community. Our results suggest that intentionally designing for enhanced social connections and social supports could contribute to increasing the belonging and persistence of individuals in the broader community. Further, feelings of belonging within affinity groups may not directly translate to a sense of belonging to the broader related community for all participants. Attention to how affinity groups function and how that function changes across demographics will help us to better employ this approach to broaden participation in BER.

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