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EDITED BY
Audra Van Wart,
Brown University, United States

REVIEWED BY
D'Anne Duncan,
University of California, San Francisco,
United States
Lisa Kozlowski,
Thomas Jefferson University, United States

*CORRESPONDENCE
Beronda L. Montgomery
✉ berondam@gmail.com

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Synergy as a strategy to strengthen biomedical mentoring ecosystems

Becky Wai-Ling Packard[1], Beronda L. Montgomery[2]* and Joi-Lynn Mondisa[3]

[1]Mount Holyoke College, South Hadley, MA, United States, [2]Grinnell College, Grinnell, IA, United States, [3]Department of Industrial & Operations Engineering, University of Michigan, Ann Arbor, MI, United States

Across science, technology, engineering, and math (STEM) fields, mentoring initiatives promote persistence among racially-diverse trainees within the biomedical workforce. Unfortunately, mentoring initiatives even within an individual college or university may be disconnected from one another, which can contribute to a lack of consistency and strategic investment. In this conceptual analysis, we argue for a synergistic strategy to biomedical mentoring, which involves rethinking disconnected approaches to mentoring and moving toward a systems design approach for strengthening the infrastructure. We offer our STEM mentoring ecosystems framework, which helps institutions survey the landscape, take stock of assets, "connect the dots" of exemplary programs and initiatives, and identify gaps and vulnerabilities in mentoring ecosystems. Action planning should involve seeking strategic synergy by bringing intentionality to the interdisciplinary collaborations common within biomedical contexts. We unpack the concept of synergy, illustrate synergy within a biomedical context, and outline multiple pathways to synergy. Readers are invited to consider ways to optimize their biomedical mentoring ecosystems using synergistic strategy as they aim to diversify and strengthen the biomedical workforce.

KEYWORDS

collaboration, mentoring, STEM (science, technology, engineering, and math), ecosystems, synergy, diversity, racial equity

Introduction

Across science, technology, engineering, and math (STEM) fields, further investment is needed to create cultures in which individuals across racial identities who are interested in STEM careers are consistently welcomed and supported throughout their academic journey (NASEM, 2023). The biomedical workforce is no exception. According to the National Center for Science and Engineering Statistics (2022), graduate student enrollment in biological, biomedical sciences, and biomedical engineering reflected small percentages of Latine/Hispanic (less than 10%), Black/African American (4%), and Indigenous (less than 1%) individuals. While undergraduate student enrollment has improved, serious racial disparities still exist in graduation rates (Bennett et al., 2020; National Science Foundation, 2019). Enrollment and attainment statistics tell only part of the story, as research has documented climate issues, including negative research environments that devalue and marginalize the contributions of STEM graduate students of color (Gámez et al., 2022; Miles et al., 2020; Perez et al., 2023) and STEM faculty women of color (Griffith et al., 2022; Misra et al., 2024; Settles et al., 2021).

While challenges continue to exist, it is also true that numerous initiatives have created inroads for the advancement of Black, Latine, and Indigenous undergraduate and graduate students in STEM (Ashley et al., 2017; Hall et al., 2016; O'Meara et al., 2018). Much of this progress can be traced to the success of key programs, including institutionally endowed and grant-sponsored initiatives that emphasize intensive mentoring and professional investment. In the biomedical sciences specifically, the Knight Scholars program has promoted persistence during high school (Marriott et al., 2022), while the BUILD Scholars program (Ceberio et al., 2024) focuses on persistence through the undergraduate years. Additional programs have promoted the success of early-career biomedical scientists as they start their own laboratory teams (Limaye et al., 2019; Oxford et al., 2020). While many specialized scholar programs serve individuals at a particular educational level, affinity clusters that focus on a biomedical topic specialty, such as cancer (Gaida et al., 2021), addiction (Ly et al., 2023), and regenerative disease (Oxford et al., 2020), have also been successful.

Cumulative research evidence has demonstrated the efficacy of these special programs; they provide a protective buffer for historically excluded individuals, often combining the strengths of mentoring from a peer cohort, research immersion, and a network of dedicated professional scientists (Packard, 2015; Sto Domingo et al., 2019; Tuladhar et al., 2021; Washington and Mondisa, 2021). While such intensive mentoring programs continue to be necessary in today's STEM environments, they may be disconnected from one another, creating inconsistencies across STEM pathways and undermining their collective power. For example, multiple programs can exist within the same institution without knowledge of the others while relying on and taxing the same mentoring resources. In other cases, the success of one outstanding program that provides mentoring for relatively few students or early career scientists may be celebrated, without an institution learning from that mentoring program in ways that inform efforts to strengthen their broader STEM community (Packard et al., 2023; Packard et al., 2024). Without a change in strategy, mentoring programs will continue to be exceptions rather than the rule for advancing racial equity within STEM fields (O'Meara et al., 2018).

The biomedical workforce cannot afford to lose the talent that they have already invested in, nor can higher education institutions afford to squander the limited resources available. Higher education institutions that provide biomedical educational pathways need to rethink approaches to biomedical mentoring and shift to a systems design approach if they want to support and sustain a racially equitable biomedical workforce. Indeed, prior work has demonstrated that a failure to acknowledge or engage the motivations of early-career biomedical researchers from different demographic groups results in a reduced interest in academic biomedical research careers on the part of these individuals (Gibbs and Griffin, 2013; Gibbs et al., 2014, 2015).

At the very least, a systems design approach means seeing effective programs as part of a larger mentoring collective, and working to "connect the dots" across programs within their institution. In the current landscape, as we acknowledge, many initiatives are doing important work to advance historically-excluded groups within biomedical pathways, albeit in small, disconnected pockets or silos. Even when advances in equity-minded mentoring take place within particular labs or departments, they may be relatively unknown to other labs and departments on the same campus; this can contribute to an inconsistent experience, which has the potential to undermine the sound investments that have been made. Alternatively, a campus may have excellent mentoring investments in place at the undergraduate level, but have relatively little available for graduate or postdoctoral scholars. Much can be gained from taking stock of collective progress within and across departments and institutions.

In this conceptual analysis, we argue for a more strategic biomedical mentoring ecosystem that moves away from disconnected efforts toward a more synergistic mentoring infrastructure. We offer the STEM mentoring ecosystem framework that we have developed and that can aid both institutions and broader STEM communities in taking stock of their mentoring assets and gaps. We outline key terminology and associated tools, while illustrating the relevance of the framework and tools for supporting the biomedical workforce. Then, we shine a light on the importance of identifying pathways toward synergy, which requires pushing against disconnected silos of knowledge and progress, and aligns with the interdisciplinary nature of many biomedical collaborations. We close with an invitation to the biomedical research community to engage with these ideas within their own contexts.

Relevance of the STEM mentoring ecosystems framework

We developed the STEM Mentoring Ecosystems (STEM-ME) framework, in which we advocate for ecosystem-wide assessment and cultivation of mentoring (Mondisa et al., 2021). The framework's terminology provides useful language and associated tools that have helped institutional teams within higher education visualize their community's strengths and areas for further investment (Montgomery et al., 2024). In an effort to promote both intra-institutional and cross-institutional learning, community members are encouraged to map their mentoring assets, including special programs and key offices, analyze the vulnerabilities of their mentoring ecosystem, such as areas stretched for resources or in need of mentor training or other structural interventions, and discuss their observations (Packard et al., 2024). Ecosystem analysis, widely used in public health and climate studies for action planning (Santilli et al., 2011; Sayles et al., 2019), is not yet prevalent in STEM higher education or workforce development. Instead, program initiatives are more typically evaluated on their own, without understanding the initiative's location within the broader ecosystem or the connection to related efforts within an organization (Mondisa et al., 2021). This leads to disconnection, where mentoring advancements exist within department- or unit-level silos, limiting intra- and interinstitutional learning (Packard et al., 2023).

Using an ecosystem analysis, an institution can examine which individuals are being served and who has been left out as a means of identifying action steps to attract participation from among those not yet included in ongoing efforts. Taking stock can also involve examining where resources are spread particularly thin relative to the demand or where there are problematic areas. These insights can inform an action plan to more intentionally distribute resources and increase the sustainability of programming (e.g., Miles and Darling-Hammond, 1998).

We consider the STEM-ME framework especially relevant for the biomedical research community, given that PIs and teams are often involved in interdisciplinary research collaborations (Aboelela et al., 2007; Ho et al., 2021; Stehr and Weingart, 2000; Lee et al., 2009; Newman, 2023) that bring together individuals across disparate departments and institutions spanning science, engineering, and medicine to advance innovation and discovery. For example, one collaboration aimed to better understand the nature of anterior cruciate ligament (ACL) injuries by partnering biomedical engineering research students at one institution with mathematical modelling students at another (Knisley and Behravesh, 2010). Another collaboration sought to connect researchers across career stages and disciplines who aimed to advance tissue regeneration (Oxford et al., 2020). Ideally, each team is not only collaborating on their particular biomedical question, but also contributing to a broader mentoring ecosystem, where they can share their distinct technical learning while also sharing strategies for advancing the biomedical workforce. That way, the mentoring resources, and associated climate, are more cohesive as trainees move from undergraduate experiences into graduate-level experiences and beyond.

Terminology

Before delving into what an ecosystem analysis can provide, it is useful to unpack the vocabulary of the STEM-ME framework (see Table 1). In our research, we found that the terminology helped individuals across the same institution, and across institutions, talk about the strengths and potential vulnerabilities within their ecosystems using shared language (Montgomery et al., 2024). The first step is to take stock of mentoring assets, referring to any formal or informal program, initiative, or structure. As mentioned before, the biomedical research community contains many key mentoring assets across all levels that contribute to workforce preparation and development pathways. These include special mentoring or scholar programs, offices (e.g., student success, undergraduate research, graduate or postdoctoral affairs, faculty advancement, diversity, equity, and inclusion [DEI]), and key individuals who are advancing mentoring on their campus or in their organization, whether formally or in the context of informal initiatives designed to advance students, postdoctoral scholars, or faculty.

Assets also exist outside individual organizations; we zoom out to consider disciplinary societies and professional development organizations from which an individual PI, team, department, or institution can seek expertise or support. The biomedical research community has many such assets (e.g., professional societies, conferences, consortia, and educational and professional development opportunities). Professional societies, such as the Biomedical Engineering Society (BMES), offer membership, meetings, and educational opportunities for individuals doing work in biomedical engineering research and development. Similarly, organizations such as The American Institute for Medical and Biological Engineering (AIMBE) and conferences such as the Annual Biomedical Research Conference for Minoritized Scientists (ABRCMS) provide opportunities to share research and develop synergistic collaborations that support advocacy and inform policymaking (Casad et al., 2016; Hulede, 2018; Lee et al., 2020). In addition, several organizations serve as mentoring resource assets to the biomedical community. For example, the Center for Improvement of Mentored Experiences in Research (CIMER) (Branchaw et al., 2020; Hurtado et al., 2017; Pfund et al., 2015) provides mentoring training and curricula via its National Research Mentoring Network to support researchers and practitioners "to enhance…biomedical-related research." Training can include leveraging resources to help PIs increase their awareness of cultural diversity (Byars-Winston et al., 2023). In addition, the Research Centers in Minority Institutions (RCMI) Translational Research Network has provided important biomedical research infrastructure that has contributed to advancing workforce diversity while advancing research on health inequities (Ofili et al., 2019).

Instructional design and educational and curricular activities may also serve as assets within organizations in biomedical contexts. Undergraduate and graduate biomedical engineering (BME) and bioengineering (BioE) programs have existed for more than 50 years with foci in physiology and medicine (Linsenmeier and Saterbak, 2020). These programs have provided classes, incubator courses, and curricular experiences to support the development of scientists (Huang-Saad and Springer, 2020; Huang-Saad et al., 2020); yet without exposure to actual practice, graduates may lack an understanding of the connections between curricular experiences and biomedical career opportunities (Vempala and Huang-Saad, 2022). Examining courses, instruction, and activities that contribute to biomedical contexts as assets may be useful in identifying opportunities for potential synergies.

Next, it can be useful to consider the mentoring stakeholders and champions within an organization. Stakeholders are people or groups who care about the investment in or outcomes of mentoring, and they include more than just mentees and mentors. For example, many campuses must consider the needs of alumni or the donor to a prominent center or regional workforce needs. Considering the needs of these stakeholders can help broaden the purview of an individual PI who is thinking about developing a mentoring program or that of an institutional leader considering sunsetting a program. A champion of mentoring works to advance a mentoring initiative, whether within their own lab, department, or institution, by persuading or motivating

TABLE 1 Terminology.

Asset	A key **strength**, such as an existing program, office, person, committee, communication mechanism, meeting structure, or policy that advances or provides STEM mentoring, directly or indirectly.
Stakeholder	A person or group in the system who **has a vested interest in STEM mentoring**, even as a means to something else (e.g., student success, diversity goals).
Champion	A person or group in a system that is **in a position to influence, encourage, or motivate others** to get actively involved or to get leaders to invest resources in STEM mentoring.
Steward	A person who is **aware of or negotiates resources** (e.g., funding, training) and who shoulders accountability for assessing and cultivating synergies within microsystems.
Gap	A group that is not (yet) being served or a service not (yet) in existence; an **absence** of mentoring.
Vulnerability	An entity or dynamic that **threatens to weaken the system**, such as a less-resourced program or an overly-stressed set of providers; areas of the system or particular populations where less attention has been paid or investments made in STEM mentoring.

Bolded text indicates keywords associated with the term.

others to see its value. Identifying champions can help when looking for possible partnerships. In the biomedical realm, this may involve partnerships across academic and clinical areas, as well as external partnerships with independent or private medical institutions or private industry with biomedical interests.

The stewardship emphasis of the STEM-ME framework encourages a focus on resourcing, sustaining, and informing the ecosystem (Whittaker and Montgomery, 2022). In our research, we found stewardship to be a novel point of discussion with regard to mentoring, as many initiatives operate in isolation. Many community members have not considered what is needed within the ecosystem at large or the importance of a steward(s) to manage and steer organizational resources and shift the reward structures for mentoring (Montgomery et al., 2024). The ability of stewards to shift institutional ecosystems is critical to a number of challenges, including the recognized gap in identity-relevant career development (Gibbs and Griffin, 2013; Gibbs et al., 2014, 2015) and support in navigating biomedical funding systems with documented biases that impact entry into and success navigating the biomedical workforce (Chen et al., 2022; Taffe and Gilpin, 2021). In our research, we found that individuals holding various leadership roles did not necessarily see mentoring stewardship as part of their responsibilities and that transitions in leadership led mentoring stewardship to fall by the wayside (Packard et al., 2024).

Tools

We developed two STEM-ME tools: an inventory to take stock of current mentoring assets and a visual map to display their presence across the ecosystem (Montgomery et al., 2024). The inventory is especially useful for affirming strengths and noticing gaps, including which groups are currently being served or left out and by whom. Even the act of trying to complete the inventory can help a campus team recognize the vast array of assets and potential opportunities for closer collaboration, including learning from successes in different domains (Packard et al., 2023). For example, upon taking an inventory of mentoring assets, a biomedical community may realize that it has many programs for early career faculty and a gap in service for postdoctoral scholars (see Table 2 for an institutional community's sample inventory worksheet). They might also consider convening a cluster of program directors to discuss any shared approaches including their preparation of mentors or recruitment strategies.

The visual map is especially useful for noticing concentrations of mentoring activity or vulnerabilities in the system, such as stressors or a lack of mentor resources within the ecosystem. For example, despite having careful stewardship and institutionalization of resources benefiting those pursuing undergraduate and graduate studies in engineering and medicine, an institution might observe a set of faculty departures in math and biological sciences, along with a major biomedical organization closing down operations in the broader community. This may create vulnerability within the broader mentoring ecosystem. They could consider exploring options to reconnect with a relevant disciplinary society in order to bolster their offerings. Figure 1 is a sample map template that could be used by an institution with this situation.

Identifying gaps and vulnerabilities can prompt a specific action plan for an ecosystem. While many leaders or PIs might imagine the need for creating new initiatives, we encourage pausing to consider whether there is a prospect for collaboration to address limitations or expand capacity. In particular, this is a time to look for pathways to synergy within the ecosystem. Next, we will examine what synergy can look like to strengthen biomedical mentoring ecosystems.

Toward synergy within biomedical mentoring ecosystems

Biomedical collaborations are common in the field, and synergies can be leveraged both by supporting workforce pathways

TABLE 2 Sample mentoring assets inventory.

Assets (programs, persons, entities)	What do they do (functions, services)?	Who do they serve?
Susan Elway, Biomedical Engineering Department Chair	• Supports departmental primary investigators (PIs) involved in program/project, including professional development and navigation of institutional policies	• Faculty involved with particular program/project
Institutional Grants and Research Office	• Support faculty PIs in (1) budget preparation and management, (2) navigating research infrastructure and policies, including those affecting undergraduate and graduate student researchers as well as postdoctoral researchers	• This is not directly shaping mentoring but this structure has helped all of the colleges stay on the same page when requests come in
Graduate School	• Supports graduate student matriculation and success • Support faculty PIs in mentoring graduate students and navigating institutional policies affecting them	• Graduate students • Graduate program directors • Faculty with graduate students in particular program/project
Office of Postdoctoral Affairs	• Supports postdoctoral researchers in navigating research infrastructure and policies • Support faculty PIs in mentoring postdoctoral researchers and navigating institutional policies affecting postdoctoral researchers	• Postdoctoral researchers • Faculty with postdoctoral researchers in particular program/project
Funding Agency (e.g., NSF, NIH)	• Provides resources for conducting research • Provides external policies and expectations for involvement of graduate or postdoctoral researchers	• Faculty PIs • Department Chair • Institutional Grants and Research Office

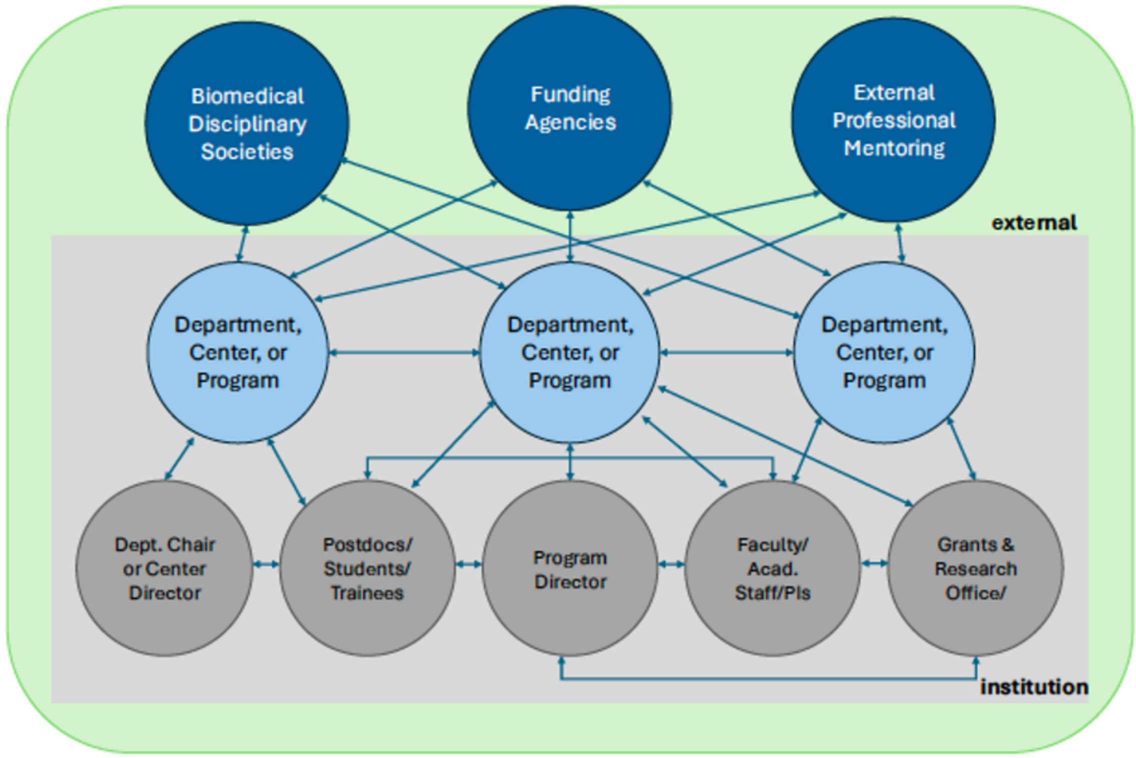

FIGURE 1
A general STEM-ME map template for biomedical organizations.

in biomedical research and by fostering innovation within and across institutional collaborators. Synergy is defined as the added value gained from collaboration (De Vries et al., 2020), in which the benefit of collaboration is greater than the sum of the individual parts (De Vries et al., 2021). Collaborating teams often create synergy when they innovate by combining services or expertise in new ways (Ye et al., 2012). Interdisciplinary teams within biomedical communities are likely to generate new options or experimental advances by working across disciplinary boundaries (Leydesdorff and Ivanova, 2021). In many studies of synergistic collaboration, the word "synergy" generates a positive valence, something to strive toward when working with others (Gaggiotti, 2012).

To create synergy, teams need to move from isolation and disconnection to intentional collaboration and strategic connections. The academy, like many other work settings, is currently set up in silos in which teams work independently without intersection or integration, and threats of "turf battles" can impede collaboration (Neill and Jiang, 2017). Even when teams would benefit from collaboration, it is not uncommon to face challenges. Nahid et al. (2012), in their study of tuberculosis diagnostics, found that different teams often worked on the same problem, often in parallel. Each team can hold highly specialized knowledge, resulting in disparate islands of expertise (Long et al., 2014). Given that resources are not limitless, intentionality is required when engaging in collaboration. Indeed, interdisciplinary collaborations can reveal hierarchies across fields, with the potential to marginalize a subset of members; collaborators need to weigh the relative balance between the trade-offs and synergies gained for each interested stakeholder (Quintelier et al., 2023).

Collaborative efforts are often impeded due to a lack of time and energy (Packard et al., 2023). In many institutions, the capacity to engage in collaboration, let alone to compare notes and learn from one another within and across institutions, is stretched thin. Further, the reward structures within most institutions, especially in higher education, are still primarily based on individual output rather than collective effort, and scarcity mindsets promote competition over cooperation (Whittaker and Montgomery, 2022). Even in collaborative published work, there is often an expectation to specify the percentage or specific granular contribution made by each party.

Innovation is needed to solve the most challenging biomedical problems. Given the existence of so many interdisciplinary collaborative partnerships that aim to innovate and tackle the vexing challenges within biomedical research and collaboration, much potential exists to innovate with the goal of advancing the diversity and culture of the biomedical workforce. We argue that adopting the STEM mentoring ecosystems framework is a productive step forward, as this can help potential partners within institutions consider identifying synergies within their institution and across institutions, rather than always thinking innovation must be new, separate, and distinct from the collective. Despite the challenges, there are pathways to synergy that individuals, teams, and institutions can undertake.

Pathways to synergy

We offer three pathways to synergy—strategies that can facilitate and advance synergy. These strategies can be especially helpful to biomedical researchers engaging in interdisciplinary intra-institutional and cross-institutional collaborations.

First, the **composition** of the collaborating team is important, as is the **willingness** to coordinate communication intentionally across their biomedical research and mentoring domains. While research expertise is certainly valuable, team members also need to be open to creating a shared vision (Lawless et al., 2024) with a spirit of "research kinship" (McCorkle, 2011). Given the potential for marginalizing members of an interdisciplinary team (Quintelier et al., 2023), collaborators need to be able to recognize the legitimacy of knowledge across disciplines (Prainsack et al., 2010). To aid in this process, adding team members who act as "network mediators" can help; these are people who are adept at brokering collaboration, breaking down silos, and facilitating the cross-fertilization of ideas (Long et al., 2014). An alternative is to leverage external facilitation from an expert in collaborative participatory design so that each collaborative partner is enlisted as part of the process (Shah et al., 2015).

Let's look at an example. The Nanosystems Engineering Research Center for Directed Multiscale Assembly of Cellular Metamaterials with Nanoscale Precision, or CELL-MET for short, is the name of a collaborative, multi-institutional biomedical Engineering Research Center sponsored by the National Science Foundation; it was established to engineer clinically significant, functional heart tissue that could be used to repair or replace damaged heart tissue (National Science Foundation, 2024). CELL-MET is composed of multiple interdisciplinary and cross-disciplinary teams from various backgrounds, with expertise spanning tissue engineering, nanotechnology, regenerative medicine, education, diversity, administration and outreach. Researchers, trainees, and staff from Boston University, the University of Michigan, Florida International University, Brown University, Fort Valley State University, National University of Ireland, NHS College, Queen's University of Belfast, Wyss Institute, Harvard Medical School, Columbia University, École Polytechnique Fédérale de Lausanne (Switzerland), and Centro Atomico-Bariloche (Argentina) work together to conduct and disseminate research, train future biomedical researchers, create mentoring best practices, and engage with industry, schools, and museums. This diverse group of scientists includes over 200 undergraduate students and student/postdoc alumni, of whom 60% self-report having an underrepresented race, ethnicity, gender, or disability status.

Collaborative activities include communications between cross-institutional members of multiple integrated engineering groups to solve issues related to their respective technical areas, as well as meeting on a quarterly basis so that teams can share research approaches, protocols, and analysis techniques across their interdisciplinary partner labs. Beyond these technical working groups, they also convene an engineering and workforce development team, a diversity and culture of inclusion and broader impacts team, and innovation ecosystem partners. These members focus on providing pre-collegiate educational and outreach programs; cross-institutional courses and co-curricular experiences; justice, equity, diversity, and inclusion mentoring training and programming; and industry education, workshops, and partnership development.

CELL-MET team members collectively participate in planning meetings for their respective teams, including annual retreats and training workshops. They also convene trainees across institutions for collective workshops on science communication, among other topics. It is notable that when the CELL-MET team meets, they adhere to particular common practices, including the use of ground rules, annotated agendas, and turn-taking, known in organizational spaces for promoting productive group dynamics, contributing to shared voice and inclusion among their diverse participants (Bowman, 2015; Holmes et al., 2016; Settles et al., 2007).

Second, using **shared language, tools, or strategies** can help teams as they collaborate, making it more likely to discover or create synergy. In their work on organizational mergers, Tarba et al. (2019) recommended using a shared language and a shared inventory of characteristics to facilitate the examination of similarities in functions and operations before examining their complementarity. In our STEM-ME work, we offered teams the shared language of *assets*, *gaps*, *stewards*, and *champions*, which teams found useful in their analyses of the mentoring ecosystems found at their respective campuses (Montgomery et al., 2024), as this also facilitated an understanding of shared qualities and differences in approaches. In addition, we guided teams in a dialogue exercise (Packard et al., 2024) in which teams were encouraged to analyze concentrations of mentoring activity in visual maps of their varied ecosystems, which contributed to both intra- and cross-institutional learning. Our findings align with research by Levites Strekalova et al. (2021) that demonstrated the value of using scaffolded collaboration dialogues to help biomedical research students from different disciplines share perspectives equitably and engage in productive mutual engagement.

For interdisciplinary teams in particular, taking time to establish shared language has been shown to be critical for interdisciplinary biomedical research in which the members from distinct disciplines are accustomed to and practiced in communicating through distinct disciplinary languages (Ravid et al., 2013). While there are many disciplinary capstone courses in undergraduate institutions, there may be a need for more interdisciplinary capstone courses to prepare emergent researchers for interdisciplinary collaboration, which can include talking across disciplines (Ross et al., 2022). Courses, whether for students or professional scientists, can be important places to gain access to professional mentoring skills, whether that is talking across disciplines or learning how to mentor across difference (Byars-Winston et al., 2023).

Further, as described by Shen (2019), engagement in synergistic discourse requires teams to step back and see their team's role in the bigger picture. This stepping back to see the collective can be supported by the use of shared strategies. Within the Alliances for Graduate Education and the Professoriate (AGEP) Promise Academy, multiple institutions worked together on a shared financial strategy that could be replicated at the state system level; they shared a goal of recruiting and retaining underrepresented faculty in the biomedical sciences and leveraged the conversion of postdoctoral appointments into tenure-line appointments (Cresiski et al., 2022). This initiative has been expanded into partnership with additional state-wide systems including California, Texas, and North Carolina.

Third, clear, **longer-term organizational supports** and sources of **funding** need to be in place that lay the foundation for teams to discover synergy. Collaboration requires investment and some leaps of faith that the investment will be worthwhile. In some cases, institutions have supported synergistic collaboration by creating an organizational center, which in certain circumstances, may draw together a budget, shared space, and dedicated personnel. For example, the Rockefeller Institute, which became integrated with CalTech, was initially founded to emphasize diversity in the biomedical sciences and to focus on strategically leveraging scientific diversity to generate major discoveries (Hollingsworth and Hollingsworth, 2000). The nature of biomedical collaborations can span a wide array of areas, from data integration and analysis to data standards (Lee et al., 2009). This means that personnel supporting synergies within biomedical "collaboratories" need to possess appropriate training in the scientific and technical aspects of the collaborative research being performed as well as long-term strategic planning efforts.

While grants that require teams to work on institutional transformation (e.g., the National Science Foundation's ADVANCE or INCLUDES, the Howard Hughes Medical Institute's Inclusive Excellence, the Faculty Institutional Recruitment for Sustainable Transformation's [FIRST] program), and collective action across multiple institutions is promising, more can be done to promote intentional collaboration within organizations themselves. At the very least, intra-institutional work can foster the intra-organizational learning necessary for action planning. Even within successful interdisciplinary collaborations, many partners are often unaware of institutional resources that they could tap into or of others who are doing work in a similar vein. Stepping back, we see the potential impact of synergistic strategies for STEM transformation at large when applied across institutions and disciplines. We argue that there are many locations from which one can work to improve the infrastructure (Packard et al., 2023). We also see a critical role for organizational leaders and stewards of the mentoring ecosystem to consider how to create the conditions at the institutional level so synergic strategies can form and thrive.

Discussion

In this paper, we offer a conceptual analysis that focuses on taking stock of the biomedical mentoring ecosystem and explores the promise of working collectively to identify strategic synergy. Working individually in silos is not effective for solving the most challenging biomedical problems, and even the most promising mentoring programs, working alone and in disconnection, will not support sustained racial equity in the biomedical workforce. Given that collaboration happens among individual PIs and their teams, we outline the importance of research kinship and being open-minded when engaging in collaboration. Collaborators can ask themselves where they are working in parallel and where there is the potential to more intentionally listen and learn from others. While it is commonplace for some lab teams to visit or host others, we encourage teams to consider how to leverage these opportunities and to extend the knowledge-sharing and strategy development to support the biomedical workforce.

As much as we advocate for the potential of synergy, there are risks in its pursuit. For example, in the process of identifying similarities and differences, teams may discover duplicated efforts and redundancies (Shah et al., 2015). In our work using the STEM-ME framework with higher education teams, unintended duplication of effort was identified in a situation in which different teams competed to serve the same group of students, with each team's efforts unknown to the other teams before the ecosystem analysis (Packard et al., 2024). Even though there are potential savings from identifying economies of scale (Ahuja and Novelli, 2017), in higher education, as in other workplaces, redundancy is closely linked to negative feelings and anxiety (Simpson, 2022). In a time when workplaces across industry have struggled with limited resources, it is naive to take stock of assets and vulnerabilities in the absence of trust about who will be involved in decision-making regarding strategic reinvestment.

Organizational leaders can consider how they create the conditions for synergy exploration by understanding the added value that comes from innovation and cross-fertilization. Which intra-organizational recognitions and incentives are in place to support the time and effort needed to intentionally collaborate? We are eager to learn about current efforts in which different teams across an institution are encouraged to generate discoveries and are supported in proposals to redirect efforts more intentionally. Multiple pathways to synergy exist, but they do require organizational stewardship.

While we acknowledged at the outset that mentoring programs are needed given the current state of STEM higher education right now, we are cognizant that such efforts do not, on their own, change the system. From a critical perspective, special programs alter the trajectories of individuals while allowing the structures and core practices of departments and units to remain unchanged (Asai, 2020; McGee, 2020). A recent National Academies of Sciences, Engineering, and Medicine (NASEM) (2019) on advancing diversity and equity in STEM fields documented multiple persistent challenges in shifting organizational and departmental cultures and climates in ways that align with racial equity, which, in turn, influences resource distributions and daily lived experiences. People of color currently enrolled in an intensive program are unlikely to transition into spaces that are ready to support their continued thriving. The number of assets available within the biomedical sciences is encouraging, as are efforts to coordinate within and across institutions, across state systems of higher education, and within national-level organizations. These movements bring us closer to seeing diversification of the biomedical workforce as a collective challenge, which means we are also closer to collective solutions.

We invite the biomedical research community to engage more fully in discussions about strategic synergy from a range of contexts and professional roles. In doing so, we can collectively identify and work to challenge the individual and organizational barriers that stand in the way of crossing over from tandem work to synergistic collaboration. With greater emphasis on our interconnections, and collective goals, we can connect our mentoring efforts to diversify, strengthen, and sustain the biomedical workforce in the future.

Author contributions

BP: Conceptualization, Project administration, Writing – original draft, Writing – review & editing. J-LM: Conceptualization, Project administration, Validation, Writing – original draft, Writing – review & editing. BM: Conceptualization, Funding acquisition, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

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