Shifting our value system beyond citations for a more equitable future

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Broadening the value system in science

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Abstract

Success and impact metrics in science are based on a system that perpetuates sexist and racist 'rewards' through prioritizing citations and impact factors. These metrics are flawed and biased against already marginalized groups and fail to accurately capture the breadth of individuals' meaningful scientific impacts. We advocate shifting this outdated value system to advance science through principles of justice, equity, diversity, and inclusion. We outline pathways for a paradigm shift in academic values based on multidimensional mentorship and promoting mentee wellbeing. These actions will require collective efforts supported by academic leaders and administrators to drive essential systemic change.

Keywords: mentorship, citations, bias, sexism, racism, equity, diversity, inclusion, wellbeing

Overview

"The most dangerous phrase in the language is: We've always done it this way." - Rear Admiral Grace Hopper

Inequality in STEMM (Science, Technology, Engineering, Mathematics, and Medicine) careers is apparent across all disciplines [1]. Despite evidence highlighting the breadth of biases, action-based solutions have not been broadly adopted, and systemic change remains elusive. Under the pressure for 'objective' metric-based 'success' and 'impact,' multiple biases are perpetuated in science. For example, flawed interpretations of data with damaging conclusions are published [2,3], including papers requiring retraction [4]. Here, our interdisciplinary, international team of women scientists publicly acknowledges and denounces the pervasive sexist and racist structures persisting within the STEMM value system. Further, we advocate to accelerate the pace of positive change in science by building on the advancements made through systematically marginalized groups, including the prior and ongoing efforts of women, Black people[1], Indigenous people, people of color, LGBTQ+, and their allies (e.g., [5–9]. We (1) highlight long-standing problems associated with narrow definitions of success and impact in science; (2) advocate for expanding measures of success beyond citations to value the multifaceted nature of scientific impact (Fig. 1); and (3) propose a new academic model that values the recruitment and retention of diverse scientists through building safe and healthy work environments (Fig. 2).

It is imperative for those holding positions of power, privilege, and visibility to take informed and strategic action rather than engaging in a performative manner. Strong actions that support

[1] ***Although we recognize this language may not be used commonly internationally, we use it here to explicitly acknowledge that systemic racism disproportionately affects the lives of Black people, particularly within the United States.***

justice, equity, diversity, and inclusion (JEDI) are essential for the accelerated evolution of our value system in science. Collectively, these changes are key to generating a greater capacity for innovation, which is essential for addressing the challenges of the present and future, such as pandemics and climate change (Fig. 2).

Pivoting the paradigm to ensure equitable evaluation in science

(1) Citation counts are biased

One of the many detrimental constructs underpinning academic science is the "publish or perish" model that celebrates the quantity of publications, citation rates, and impact factor scores as the primary, and often sole, indicators of success and impact [10–12]. Citation metrics, which have been widely used across most research areas due to their quantitative nature and easy estimation, influence career advancement at all levels including graduate opportunities, funding success, career positions, awards, distinctions, and tenure and promotion. There is no doubt that historical demographics of faculty and those in academic leadership positions [13–16] have contributed to the lack of diversity among the most-cited scientific authors. While there have been recent successes in increasing diversity among trainees and early-career researchers [8,9], differential recruitment, retention, and promotion rates with respect to age, sex, gender, race, and ethnicity continue to perpetuate the lack of diversity among all career levels of scientists [14,17–19]. This issue is self-perpetuating due to reliance on citation metrics, which reflect deeply entrenched biases and exclusionary networks that disadvantage systemically marginalized groups and the biases in these metrics continue to rise globally [20].

Sexism in science publishing is ubiquitous. Evidence demonstrates that women (which we use here as an inclusive term[2]) are uniformly less cited than men, even though this issue is consistently well-acknowledged [21–24]. In a recent study examining research across 13 STEMM disciplines, the citation gap between genders was as large as 30% [16], and this gap has been documented across a breadth of journals [25]. These patterns are partially explained by men exhibiting higher rates of self-citation [22,23] and women having shorter career lengths than men [16]. However, in comparison to men, women receive more manuscript rejections [26–28], are less likely to be published in prestigious journals (which typically have high citation rates) [29], and are less likely to be invited to write commentaries [30]. These issues may stem from women's scholarly writing being held to a higher standard than men's by editors and peer-reviewers, which places penalties on women's productivity, with excessive time spent reworking old research at the cost of conducting new research [31]. Moreover, the impact of unprofessional peer reviewer comments, defined as "any statement that is unethical or irrelevant to the nature of the work" [32], have disproportionately negative effects for women and non-binary people relative to men [32].

[2] *Throughout this manuscript, we use the term "women," by which we intend to respectfully include and acknowledge the experiences and challenges of all who identify as women and/or womxn and also acknowledge that these and other challenges also exist for non-binary individuals.*

Pervasive racism in academia also drives substantial and systemic biases in publication rates, citation rates, and editorial positions [33]. Publication-related metrics show distinct patterns of bias against racially and/or ethnically diverse scientific teams, which experience more than 5% lower acceptance rates, and fewer citations than less diverse author teams [34]. Citational segregation–where authors prefer citing authors from the same racial/ethnic group(s)–has been demonstrated with white authors citing other white authors more frequently [33]. This particular bias further reduces the circulation and intellectual acknowledgement of non-white scholars' work and the diversity of viewpoints they bring. Additionally, "high-quality" research is implicitly associated with high-income countries [35], thereby limiting the dissemination of research by scientists from lower income countries. Moreover, because 98% of scientific journals are published in English, success is related to English proficiency or access to additional editorial support. Scholars who are not fluent in English are at a distinct disadvantage in the publication process, further exacerbating the global gap in citations and research dissemination [36].

Together, gender, racial, and other biases interact and accumulate, often elevating cis white males to levels of recognition much greater than are deserved given their contributions to science [37,38]. As such, the unwavering focus on citation-based metrics as indicators of success ignores the breadth of scientific evidence showing these metrics are unreliable, inaccurate, and damaging to all STEMM disciplines. Continued use of these metrics perpetuates substantial gender, racial, and ethnic biases, as well as reduced representation of diverse scholarship.

Many efforts to improve diversity in STEMM disciplines have not yet been successful [39–42]. In fact, gender and racial citation biases remain or have even worsened over the last half century [16,21–23,33,34,43], highlighting that efforts to change the system have, by and large, failed to remove systemic biases. Clearly, assessing scientific impact, and thereby the value of an individual's scientific contribution, exclusively–or even primarily–through citations of peer-reviewed literature reflects and amplifies the existing numerous biases that remain embedded within academia. Reliance on citation metrics as the primary gauge of impact will continue to limit the advancement of marginalized groups and diminish their scientific contributions [33], representing a loss of diverse talent, perspectives, and approaches.

(2) Expanding scientific impact beyond citations

Ignoring the breadth of areas where scientists have strong impacts creates an unduly narrow view of the many avenues through which scientists can contribute to intellectual advances, applied science, and equitable communication and translation of science to the public (Fig. 1A). This narrow view excludes the real-world impacts within the scientific system (Fig. 1B). Even if citation metrics were not biased, using citations as a proxy for success supports the false paradigm that scientists lack impact if they do not (or cannot) publish, and/or have chosen "alternative" career paths – a phrase that falsely suggests academic roles are the only dominant or valued careers for scientists [44,45]. Notably, scholars holding academic positions with high

teaching loads, mentoring responsibilities, service requirements, and/or administrative work, as well as those who have chosen careers outside of academia, make critical and diverse contributions to science. Non-academic careers often place less emphasis on publishing, or allow less time to lead publications, but nonetheless reflect influential routes for training new scientists, moving science broadly into the public realm, and informing critical policy and decision-making [46,47].

Another key avenue of impact on the scientific system is through training upcoming generations of scientists. This role necessitates diverse mentoring and pedagogical skills essential to attract, engage, retain, and elevate scientists-in-training from different geographies, social-cultural backgrounds, and career paths. Mentorship is a dynamic, multidimensional process [48,49] that includes, but is not limited to, instructing (e.g., teaching in the classroom, laboratory and/or field), modeling (e.g., showing by action), sponsoring (e.g., going beyond what is mutually beneficial), counseling (e.g., listening and normalizing), networking (e.g., providing access), and advocating (e.g., supporting). The benefits of multidimensional mentoring across career stages, especially by mentors with multiple identities from marginalized groups (i.e., intersectional identities), are critical to increasing representation, recruitment, and retention in the scientific system [50–56]. Good mentors can foster a sense of belonging in science for mentees with diverse backgrounds [57], especially if the mentor belongs to, or strongly associates with, a particular identity, emphasizing the importance of inclusive representation in science.

Beyond the university classroom and research group, valuing the broader impacts of research is also critical. Dissemination of scientific knowledge through public outreach and media engagement, societal service through science communication, and the involvement of local communities in the science being performed on their land and ecosystems all have the potential to center communities outside the university in work on critical topics such as public health and climate change [58,59]. Additionally, these intentional actions can aid in restoring public trust in science and promoting the advancement of diverse groups in STEMM careers (e.g., [60]). In fact, funding agencies (e.g., Natural Sciences and Engineering Research Council in Canada, The National Science Foundation in the United States, the Research Excellence Framework in the United Kingdom) are now including these contributions in the evaluation of the quality of researchers, demonstrating that funding bodies are beginning to play a critical role in normalizing and rewarding the work that scholars do to connect to communities, and are key contributors to the valuing of this work. Together, this shift in evaluation criteria indicates that quantifying these impacts is possible and meaningful to STEMM and society more broadly.

(3) Broadening the system to value mentorship, diversity, and well-being

Here we discuss how broadening of the definitions of success and impact provides an essential foundation for evolution of the academic system and STEMM fields. Through valuing multidimensional mentoring, we can promote decisive actions to improve justice, equity,

diversity and inclusion, and ultimately drive a transformation to a fair and safe STEMM culture (Fig. 2).

Valuing the impact of multidimensional mentorship

High-quality mentorship greatly benefits mentees, since mentors are essential in determining career outcomes [61,62]. Research examining a wide range of mentoring relationships (e.g., in government, hospitals, business) demonstrates that deep engagement in mentorship leads to a greater sense of job satisfaction, higher commitment to the institution, and higher career success for mentors [63]. Cultivating these outcomes within STEMM could reduce attrition rates that are often associated with low levels of job satisfaction [64] and a lack of institutional community [65]. Within academia, therefore, outstanding mentorship is invaluable [66,67]. However, this mentorship is traditionally quantified by mentee productivity, which is assessed by traditional metrics (e.g. [10]) that have significant biases (see section 1 above). These metrics fail to acknowledge the diverse value of mentorship and thus re-evaluating mentoring practices and how impact is measured will benefit a diverse and intersectional group of early-career scientists [68,69]. We propose that a broader lens of mentorship quality be acknowledged and employed by academic institutions and funding agencies, which would provide a more holistic measure of scientific impact and reward high-quality mentorship (Figs. 1 and 2).

Holistic valuation of mentorship quality includes the contributions from mentors and the achievements of mentees [52,70,71]. In addition to research productivity, metrics encompassing the breadth of mentorship dimensions can incorporate the mentees acquired skills, tools provided to the mentee, mentee retention, career commitment, self-efficacy, mentee satisfaction, and overall group culture [72–74]. Mentorship quality could then be quantitatively tracked by institutions throughout an individual's career within or outside of academia using surveys such as the Global Measure of Mentorship Practices as adapted for STEMM postsecondary education [75]. These metrics could be compared empirically against institutional or national statistics to gauge scientific impact.

Institutions should also elevate strong mentorship by both establishing internal awards for mentor excellence, and increasing the weight of such awards in promotions or tenure assessments. Awards such as the National Science Foundation's Presidential Award for Excellence for Science Math and Engineering Mentoring (PAESMEM), the Australian Museum Eureka Prize, and the Nature Research Awards for Mentoring in Science already exist to recognize outstanding STEMM mentors. In addition, placing value on mentorship by funding agencies (e.g., National Science Foundation's Broader Impacts: [76]; NSERC contributions to training [77]; Athena Scientific Women's Academic Network (SWAN) Award Scheme [78] creates further incentives to achieve mentorship excellence. These prestigious recognitions, coupled with funding and incentives to support mentees from marginalized groups, represent

strong steps forward in valuing mentoring and highlighting the efforts and impacts of individuals working to support the next generation of diverse STEMM researchers.

Promote justice, equity, diversity and inclusion in science

While multidimensional mentoring will facilitate a more inclusive culture, specific strategies are needed to change the systemic sexism and racism that pervade academic institutions [79,80]. A first step is to identify barriers to diversity, followed by policies and training designed to support transformative institutional change [79]. These include shifting community culture through communication, collaboration, and training to support interventions and leadership. For example, transitioning from a gatekeeping to a groundskeeping approach at all levels of the academic hierarchy is a key component of the required shift in culture to address pervasive obstacles to justice, equity, diversity, and inclusion [81].

For these efforts to be achieved throughout the scientific community, faculty need to be educated and supported with structured academic programs that embed these principles in teaching, research and mentoring (e.g., [82]. For example, training in inclusive pedagogical approaches (i.e., inclusive or deep teaching: [83,84] can be mandated by institutions. This training may also include critical pedagogy that examines and challenges the systems of oppression that shape society [85–87] and promotes both the intellectual growth and well-being of students and mentees [88].

Unfortunately, large gaps in implementing effective strategies to enhance justice, equity, diversity, and inclusion in science still persist. Over the last decade, a range of initiatives in academia, industry, and government have been implemented to support the attraction, retention, and progression of systemically marginalized groups in STEMM careers at national and international levels. To normalize and move these initiatives forward, we must leverage the many recommendations that have already been made for justice, equity, diversity, and inclusion in science [5–7,82,89,90]. Evaluating these actions and policies within a scientific framework and identifying the best practices will help implement effective strategies [91]. Scientific institutions and funding agencies must implement initiatives that address the systemic sexism and racism in recruitment, grant funding, and promotions. Both political and institutional commitment are needed to strategically implement meaningful equity and inclusion approaches with effective accountability mechanisms in place [e.g., 92].

Transformed STEMM Culture: Supporting a safe and healthy environment

The role of inclusive mentoring practices (e.g., sponsoring, counseling, networking, and advocating: Fig. 2) is unequivocal in providing essential tools to foster justice, equity, diversity, and inclusion for mentees, preventing toxic mentor-mentee relationships, and overcoming barriers and access in STEMM careers [93,94]. Social belonging and valuing of multiple identities in science reinforces achievement [9,82,95,96], and diverse teams have been shown to

increase the rate of innovation and collective creativity [97–99]. While good mentorship can foster a sense of belonging in science for the mentee, relationships of many mentees from marginalized groups with their mentors – who are often from the majority group – are not positive, leading to health issues such as insomnia and anxiety [100], and lower retention of these groups in science (reviewed in [79,90]. To effectively mentor, all mentors – especially those who are not familiar with the experiences and perspectives of systemically marginalized scholars – should seek appropriate training (e.g., anti-racism, cultural competency, unconscious bias, microaggression, allyship, LGBTQ and gender identities, disability and ableism, etc.), connect to communities that are working towards creating justice, equity, diversity, and inclusion, and engage in institutional change already underway.

Of particular concern is recent work highlighting the declining mental health of many academics, and a growing crisis at the graduate level [101]. Graduate students are at least twice as likely to experience mental health challenges, such as anxiety and depression, compared to the general educated population [102]. This trend is even more striking for women of color in STEMM, who are facing systematic sexism and racism, along with daily microaggressions and safety concerns [103]. Sexual minorities and LGBTQ+ identifying people are also subject to discrimination that adversely affects their well-being, mental health and, ultimately, retention in STEMM fields [56,90]. Laboratory work, field work, and simple existence in the academy can often place marginalized groups, including those with disabilities, at risk of injury, harassment, bullying and assault (e.g., [89,104–106]. To combat these challenges, specific strategies for safety and wellbeing [107] must be supported at the research group, institutional, and funding organization levels.

Moreover, destructive mentoring has often gone unchecked in academia [105], often because of the appearance of a superficially productive, well-functioning or supportive working environment. This is in large part due to power dynamics within the mentor-mentee relationship, as academia was constructed on a model with a top-down hierarchy (Fig. 2). Key future directions to redress this issue include proactive policies at the institutional and departmental levels, which could include formalizing mentee and advisor formal responsibilities and expectations [108,109]. Initiatives can be tailored to train mentees so that they are empowered to manage their relationship with their research mentors, and for faculty to advise, educate, and supervise using inclusive techniques [94]. Further, there should be clear processes and procedures to change and ultimately affect change in behaviours displayed by potentially abusive mentors and significant consequences to hold mentors accountable and to prevent negative impacts on future mentees (e.g., [110]). Actions such as facilitating safe ways in which mentees can provide feedback to their mentor – whether positive or negative – is a start to empowering mentees and aligning expectations [111]. Institutional oversight in developing a strong mentorship culture, support for mentor-mentee training, and responsibility for administrative interventions are critical aspects of ensuring a safe environment for all.

Institutions are at the foundation of creating a culture that promotes community wellness, beginning with a clear mission that aligns with the safety and health of mentees and mentors, especially those from marginalized groups [112]. Indeed, it is the institution's responsibility to ensure there is specific training focused on effective mentoring practices and modelling wellness for mentees [79,113]. Mentees and mentors need to be trained to appropriately flag, assess, and address mental health and safety concerns using targeted and early-intervention roadmaps in safe spaces. This training should be made readily available via a variety of modalities, such as mental health first aid training (e.g., [114]). An enhanced focus on health, safety, and accessibility in STEMM, as well as institutional support for mentorship assessment and growth, will lead to improved retention of diverse scientists and increased community health and wellness (Fig. 2). While it has become increasingly standard for academic institutions to publicly profess commitments to justice, equity, diversity, and inclusion, without sufficient investment of time, energy, and funding, these commitments will remain performative [115].

Conclusions

To create an inclusive and innovative science community, the scientific system needs to move beyond the current narrow measures of success and impact to focus on holistic assessment (Fig. 1). Acknowledging that there is a diverse range of contributions and career pathways will broaden the value system in science. By embracing inclusive approaches and not forcing people to assimilate into sexist and racist norms, we can grow a more equitable model for science that addresses injustices. The challenges associated with changing a deeply embedded institutional history, culture, and structure toward a different inclusive value system will require institutions to champion a 'new norm' to bring change at a global scale. Such a shift must be embraced by all, and led by those currently in positions of power and privilege. This shift requires not only specific proactive actions and reforms to institutionalize change, but also mechanisms to monitor implementation and provide feedback optimizing an adaptive and dynamic structure.

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Figures

Figure 1. Science is suffering from observational bias in our value system. This bias is analogous to the streetlight effect where A) citations are valued because that is where we look, despite the fact that they perpetuate gender and racial biases as metrics of success. We advocate for B) an expanded view of success and impact that is multifaceted and includes critical areas of mentorship, inclusion and diversity.

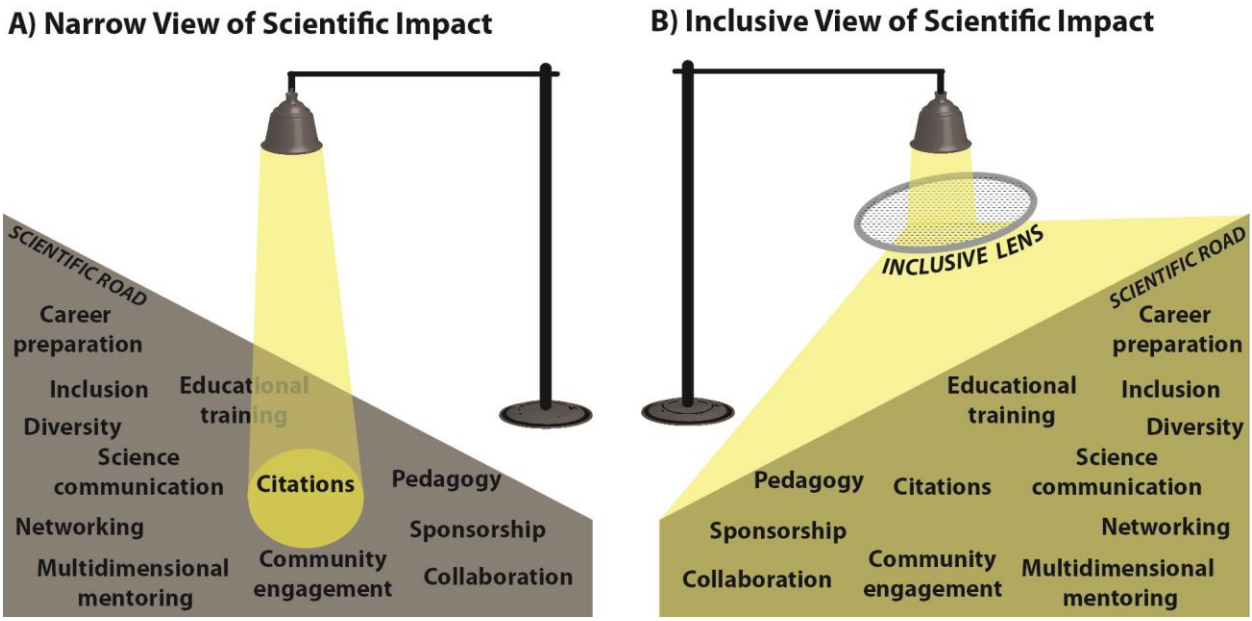
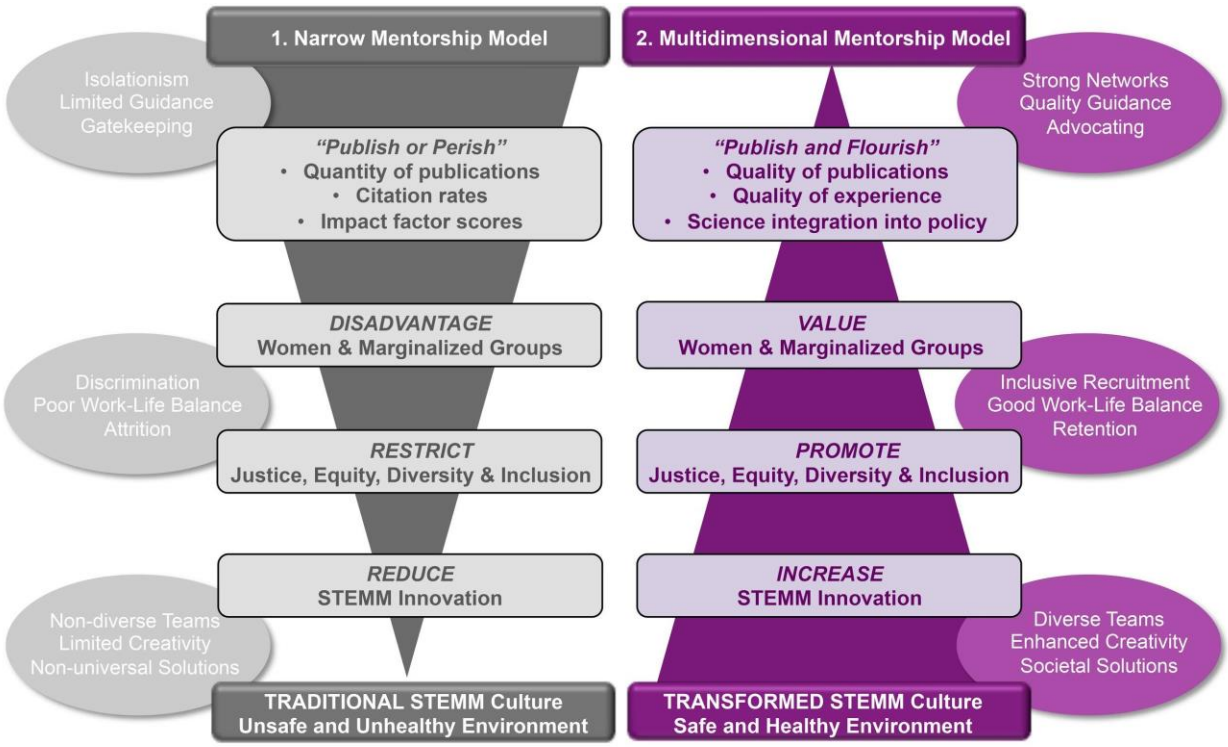


Figure 2. Here we show two models for the disciplines of Science, Technology, Engineering, Mathematics, and Medicine (STEMM). We argue that the narrow mentorship model based on the top-down "Publish or Perish" approach to success and impact facilitates processes that lead to a reduction in diversity and innovation (illustrated by the inverse gray pyramid), and a detrimental STEMM culture that supports a limited subset of scholars. By contrast, a multidimensional mentorship model supported by those in leadership roles (e.g., by university and college presidents, chancellors and provosts) working across academic institutions will incorporate diverse measures of success and impact to create system-wide change (illustrated by the purple pyramid). We argue that the latter approach can lead to increased innovation that will transform STEMM culture where processes which support the two models, and outcomes of each, are side highlighted within the oval shapes.



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