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Perspective

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Framework for department-level accountability to diversify engineering

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Abstract

Diverse teams are more innovative and creative. Nevertheless, science, technology, engineering and mathematics disciplines, including bioengineering, continue to fall short in increasing representation from persons from groups historically excluded because of their ethnicity or race. Many universities have crafted strategic plans to increase diversity; however, university-wide policies often fail to result in notable changes in microcommunities, such as departments and undergraduate or graduate programs. Therefore, departments may benefit from guidelines not only to craft effective diversity, equity and inclusion (DEI) plans, but also to measure progress towards achieving specific DEI goals. In this Perspective, we present a framework for building, assessing and continuously improving strategic plans to improve recruitment and retention and to make departments more inclusive, including the collection of demographic data, the establishment and assessment of DEI plans, specific goal setting and assessment of achievements, with specific examples and guidelines, which will ultimately help departments to become inclusive working environments.

Sections

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Key points

- To advance innovation and improve workforce development in science, technology, engineering and mathematics (STEM), higher education must recruit and retain students from historically excluded groups.
- Institutional plans calling for increasing inclusion are useful guidelines but are typically not actionable at the department level.
- Many departments have yet to evaluate or reflect on their community and develop actionable plans to build a diverse, equitable and inclusive workforce.
- A departmental-level framework, considering department-specific circumstances and missions, outlines actions, activities and goals towards a more inclusive and diverse workforce.
- Effective and lasting diversification of STEM requires department and programmatic accountability.
- Systemic problems demand systemic solutions. Departments, professional organizations and government agencies should support the development of action plans.

Introduction

Diverse teams bring various perspectives to problem solving and produce the most innovative solutions[1–3]. However, despite years of efforts to diversify science, technology, engineering and mathematics (STEM) disciplines in the United States, the proportion of individuals from Black, African American, Latine (that is, Latino/Latina) and Indigenous American groups remains low in STEM, compared with their respective representation in the US population[4]. For Black and African American communities, representation in STEM has even worsened over time (Fig. 1). Through systemic exclusion, institutions of higher education for STEM professionals, including for biomedical engineering and bioengineering, are underperforming in terms of diversity, equity and inclusion (DEI) and are not meeting the needs of workforce development. At many institutions of higher education, inclusion statements, education for all or other equity-based missions are prioritized at the highest administrative levels. However, faculty and staff are typically developing and implementing activities that broaden participation in STEM. Because of this department-level activity, we argue that the department is the place for plans and actions to diversify disciplines and address the call to develop the next generation of innovators.

The need to establish and maintain diverse teams in STEM is not unique to the United States[5–10]. For example, gender disparities in STEM have also been reported in Mexico[11] and Canada, with their own distinct challenges. People from Indigenous communities and people from rural areas are less likely to enroll in STEM programs in Mexico[12] and Canada[13–15]. In Belgium, engineering career tests have been developed to increase students' knowledge of future career opportunities and sense of belonging[16]; these tests have been found to support self-efficacy and retention of those who tended to leave engineering[17]. In the United Kingdom, the retention of Black scientists is failing at every level of academia[18], and the Royal Society of Chemistry has highlighted systemic inequalities in chemical sciences, showing that these barriers propagate from the classroom to industry[19]. In India, systemic exclusion is seen within the caste system[20]. China has undertaken substantial effort to address disparities within its educational systems, which are exacerbated by low social mobility, geographical barriers (that is, rural versus urban) and socioeconomic inequalities[21,22]. In both China and Japan, various strategies have been used to reduce persistent gender gaps in STEM fields. For example, China has legislated gender equity from compulsory education to higher education to improve women's educational opportunities and has separately prioritized STEM educational opportunities, which by default has increased the number of women in STEM fields[23]. In Japan, institutions are introducing quotas to increase the number of students they admit in STEM fields, with the government considering subsidies to incentivize[24]. In African countries, gender disparities and other forms of inequity in STEM fields may have been propagated by historical political patriarchy, and countries have tried distinct approaches for reform, although many of the initiatives are focused on funding women in science[25]. For example, in Kenya, women represented only 26% of scientific researchers in 2010 (ref. 26); institutions and national societies have developed strategies to support women in science ranging from grant development support to travel support and to leadership professional development. In South Africa, the number of female staff members in higher education institutions has increased from 44% to 49%, with publications that include female co-authors increasing from 31% to 36%, between 2005 and 2020, across STEM disciplines, although Black women still lag behind in representation, demonstrating a continued need to disaggregate data and develop strategies to reduce the barriers to publication[27]. This intersectionality of STEM disparities has also been highlighted in Brazil, where women make up 57% of the population and Black individuals represent 54% of the population, but Black women make up only 6.4% of the highest college entrance exam grades, and only 17% of all professors with PhDs in Brazil were Black individuals[28]. Thus, the need to increase inclusion for diverse representation in the educational systems is evident. As the most pressing problems are global in nature (for example climate change), disparities in STEM education will ultimately adversely affect the lives and livelihood of current and future generations. Therefore, higher education must react to increase the number of diverse and innovative teams in STEM.

Systemic, structural and institutional barriers, enforced by policy, tradition or both, make change in higher education institutions difficult to manoeuvre and may prevent inclusive participation in STEM programs[29]. Structural barriers may be invisible because they persist in communities as 'just the way things are'. For example, in the United States, it is common for external letters to be used within the tenure and promotion process, and these letters often ask, "Would this person get tenure at your institution?" Given different resources and institutional structures, this question effectively becomes a barrier to promotion. Systemic barriers encompass the participation of systems (that is, political, legal, economic, residential, health) that underlie institutionalized structures. Together, systemic and structural barriers culminate in unequal and inequitable treatment of distinct groups. Shielded by the academic myth of meritocracy, these barriers are simultaneously more pervasive and more difficult to critique than interpersonal racism. Although barriers are endemic within an institution, many of them may be addressable within a department (Table 1).

The impact and accountability for institution-level DEI statements reside with those who carry out the university's day-to-day activities, which often falls under the purview of a department or

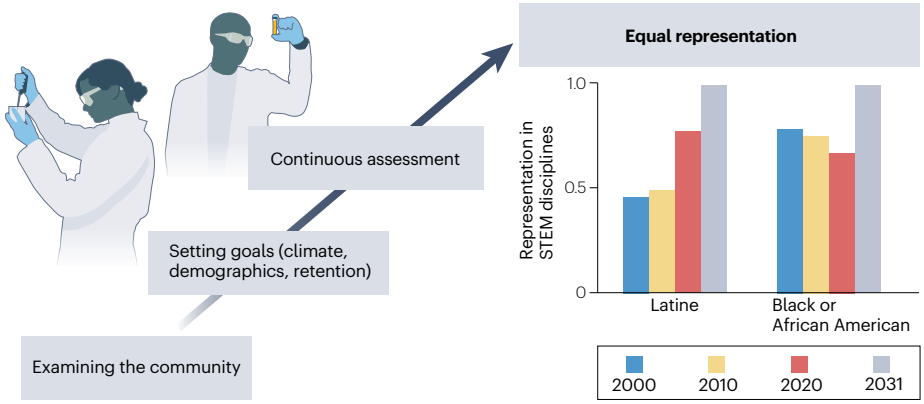

Fig. 1 | Equal representation in science, technology, engineering and mathematics disciplines. Institutions should establish plans to examine their community, set goals and assess these goals to increase representation and innovation in science, technology, engineering and mathematics (STEM). However, Bachelor of Science attainment in STEM disciplines for US citizens or permanent residents who identify as Black or African American has declined in the United States from 2000 to 2020 relative to their representation in the US population of 20 to 34 year olds. Those who identify as Latine (Latino/Latina) see growth in Bachelor of Science attainment, and this growth needs to continue in order to support the STEM workforce in the United States. Additional strategies are needed to achieve parity by 2031. The *y* axis signifies the level at which a particular population is represented in STEM disciplines, where a value of 1.0 indicates that a group is represented at the same percentage that it is in the general population. Sources: Population data are from the US Census Bureau, using the Decennial Census from 2000, 2010 and 2020 for the United States, with demographic breakdown by age and sex (PCT12A–PCT12O for 2010 and 2020 and PCT012A–PCT012O for 2000); degree completion data are from the National Center for Science and Engineering Statistics (NCSES), IPEDS Completion Survey of Bachelor's Degrees in Science and Engineering (S&E) disciplines from 2000 to 2022, broken down by race and ethnicity; total science and engineering degree attainment was calculated as total science and engineering degrees with those of unknown race or temporary visa holders removed.

similar unit[30]. Unfortunately, although university-level DEI statements are well intentioned, many departments remain insufficiently staffed, resourced or equipped to successfully reduce barriers and implement DEI. In particular, the overall goals and vision at the department level, which must align with the vision of the college, school or institution to garner support and resources from upper administration, may be in conflict with prioritizing DEI. Furthermore, in some regions, discussion and activities related to diversity initiatives have been discouraged and defunded[31].

Importantly, from the standpoint of a department, knowing where to start and how to assess the efficacy of current and potential strategies may be challenging. The tug of war on financial and personnel resources and constraints on time can result in inaction. Many departments already support initiatives through their individual faculty's effort, for example through a National Science Foundation (NSF) CAREER award or other outreach, which can initiate conversations about departmental goals and assessment (Box 1). Such initiatives and activities are typically led by individual faculty members; however,

Table 1 | Structural and systemic barriers in a departmental setting

Practices	Outcomes
Structural barriers	
Non-transparent, non-formalized internal hiring and promotion processes	Can lead to raising or lowering the bar depending on individual biases
Rules and policies in place are based on cultural norms that cannot be changed	Does not account for intercultural differences and assumes only one definition of 'merit'
Policies and consequences for not meeting expectations are non-transparent and inequitable	Unequal administration of rules, preferring one group to another and reducing success
Grading practices that give preference to one group over another	Grades that are not based on student demonstration of knowledge
Non-formalized mechanisms for mentoring, teaching and service assignments	Inequitable service and teaching distributions; disproportionate overloading of underrepresented faculty[46]
Systemic barriers	
Lack of representative faculty and staff despite attempting to recruit and train diverse students	Fewer applications from prospective students, faculty or staff
Messaging that certain student groups are more desirable than others based on race or gender	Decreased sense of belonging leading to failed student, staff and faculty retention, and lack of career advancement
Lack of funding available to recruit and support needs of department members	Limited success of existing efforts to increase diversity

Box 1

Grassroots efforts create and support diversity, equity and inclusion

Sustainable improvements to the culture in a department, program, college, school and university require top-down regulations and support from administration, as well as bottom-up activities developed by students, faculty and staff. Grassroots efforts initiated by individual university members allow nascent projects to be tested and, eventually, adopted by the university for scale-up. For example, the ADVANCE program funded by the National Science Foundation (NSF) funds projects for several years with the expectation that the university funds the approved project for long-term adoption, extending the ADVANCE programming indefinitely beyond the NSF funding period. In addition, the NSF provides the opportunity to pilot projects through their mandate for the inclusion of broader impacts in all of their funded research grants. These efforts can be large, focused educational grants (for example ADVANCE or Research Experiences for Undergraduates (REU) Sites), which can lead to increased hiring of faculty members[49], staff and students. REU Sites and ADVANCE programs are accompanied by equity-focused and inclusion-focused programming, such as workshops or webinars, to broaden participation that can outlive the NSF funding cycle. At smaller scales, individual faculty can request small amounts of money for individual REU students, adding funded opportunities for students from historically excluded groups, or to fund programming and research experiences for local students (kindergarten to grade 12) from the area. Universities with serious commitments to DEI can use small amounts of money to grow these programs for sustainable change.

substantial and sustained impact requires concerted plans to address systemic barriers.

Department-level actions can substantially improve diversity in STEM. A 2020 study of three STEM departments in the US Midwest credited the successful hiring and retention of Latina faculty to improved promotion strategies, structural signals of inclusion, community support and integration of all voices at the departmental level[32]. A diverse faculty body also has a positive impact on student success. Black, African American, Latine and Native American community college students get better grades, are less likely to drop out of classes and are more likely to persist in their degree when taught by instructors of the same race or ethnicity[33]. Furthermore, evidence from industrial and academic settings demonstrates the positive impact of diversity on sector productivity; for example, a 2018 study from the Boston Consulting Group correlated diversity in management teams across dimensions that included gender, national origin and educational background with innovation performance[34]. In the context of academia, ethnic diversity in research teams leads to higher levels of innovation[35], publications in higher-impact journals[36], and increased citations and research impact[37].

In this Perspective, we discuss department-level actions and assessments to diversify engineering in STEM. As members of a network of more than 450 faculty, representing more than 100 engineering departments in the United States (BMEUnite), who routinely meet to address racial and ethnical inequities in biomedical engineering[38], we aim to evaluate progress towards DEI efforts through a quantitative 'baseline' of diversity in our discipline. However, inconsistencies across the type of demographic data reported, as well as the distinct situations of different departments (that is, private versus public, location, size, populations served), make it challenging to compare demographic diversity, not only in biomedical engineering and bioengineering but in STEM in general[39]. Initiatives to increase DEI in engineering also greatly vary in the European Union[40]. Therefore, rather than considering what cannot be done, we propose department-level actions and a framework for standardizing data reporting, including building a rigorous plan to improve DEI, assessing the plan and sharing the results. We envisage that a consistent framework can be scaled to apply to different constituencies at a given institution and department.

Framework for departmental-level DEI action

The proposed framework for departmental-level DEI action is modelled after the college-level Diversity Recognition Program, which was introduced in 2016 by the American Society for Engineering Education (ASEE) (Box 2) but has yet to be broadly implemented across engineering departments. Our proposed framework may feed into a professional organization-sponsored DEI recognition program, enabling departments to make a public pledge about their collective intent

Box 2

American Society for Engineering Education diversity recognition program

The American Society for Engineering Education diversity recognition program is a call to action for engineering deans. The diversity recognition program was introduced in 2016, asking deans to commit to developing a diversity plan for their engineering programs with the input of national professional organizations, such as the National Society of Black Engineers, Society of Hispanic Professional Engineers, Society of Women Engineers, American Indian Science and Engineering Society and others. This plan includes a definition, vision, assessment, priorities, goals, commitment to training, accountability plan and assessment. In addition to the plan, the deans should commit to pipeline activity, partnerships with non-PhD-granting engineering schools, and the development and implementation of strategies to increase the number of women and persons historically excluded based on ethnicity and race in the faculty. As of September 2022, deans of 236 engineering and technology schools have pledged to increase the enrolment, retention and graduation of women and persons historically excluded based on ethnicity or race in engineering, and to increase faculty and workforce diversity over the next 10 years (Deans' commitment).

Box 3

Departmental commitment to diversity, equity and inclusion

Departmental commitment to diversity, equity and inclusion (DEI) should include a public statement, for example by signing the following pledge to track demographics and develop a department action plan:

- As department heads or program chairpersons, we need to actively improve diversity, equity and inclusion (DEI) efforts for our faculty and our students. Many of our colleges have committed to the American Society for Engineering Education diversity recognition program, and we shall further implement activities and actions at the department and program level.
- Department faculty are deeply connected and engaged with our students and trainees to better develop a diverse, inclusive and equitable community at the department and program level. These efforts require establishing goals and actions for our communities, while resourcing and assessing to the best of our ability. As department chairs, we realize that we are uniquely positioned to initiate and incentivize activities that will increase the participation in our engineering fields.
- We thus pledge to develop a DEI plan with inclusive input of our students, faculty and staff to evaluate our current demographics and articulate a vision of a diverse and inclusive department or program in the context of the institutional plans; establish data-driven department-level or program-level goals to improve recruitment, retention and advancement of our members; implement activities, establish outcomes and define resources; and assess the plan to define new or continuing goals.
- The collective engagement in actions to meet departmental and program diversity visions will not only make each department a more inclusive and engaging learning environment, but alter the face of the bioengineering profession. We recognize that improvements in the department and program environment for historically excluded groups will benefit the whole. The most powerful testament to an inclusive environment is one in which those not underrepresented serve as advocates and allies for colleagues who are persons historically excluded based on gender, ethnicity or race.

Of note, several states in the United States and other regions may defund DEI efforts or disallow efforts that fund diversity offices or use of diversity statements in hiring at public universities. If this is the case, we encourage the emphasis of innovation through unique perspectives, citing that diverse teams increase innovative and creative thinking[1–3]. Additionally, although departments may not be able to provide public DEI statements, DEI efforts can be implemented without referring to DEI directly. In particular, structural and systemic barriers can be reduced by improving the departmental climate and increasing transparency in hiring and promotion processes[49].

to improve DEI, which includes signing a commitment statement to develop an action plan (Box 3), collect and review demographic data (Table 2), and develop a DEI plan, which is then approved by the department (ASEE recommends less than five pages).

Defining diversity

A number of parameters for defining diversity are identified by the US federal government, but they do not account for all areas of diversity and representation within the population or an institution (Box 4). Therefore, in addition to data on gender, race and ethnicity (Table 2), other demographic information may be collected, such as veteran status, first-generation studentship, LGBTQ+ identity, past or present socioeconomic circumstances, physical and emotional or mental abilities, and intersectionality between multiple underrepresented groups. However, people may not want to self-identify further for privacy reasons[41], for concerns about discrimination or mistreatment[42], or because they do not identify with the classifications[43]. Importantly, the goals of the DEI plan and their assessment should be tailored to the diversity relevant to the department.

Diversity, equity and inclusion plan

A DEI plan must reflect the commitment of an entire department, including financial, faculty and staff, as well as infrastructure resources, and should not be relegated solely to a committee. The DEI plan should include demographic evaluation, goals, implementation (activities, outcomes, resources) and assessment (Tables 2 and 3, and Fig. 2). Ultimately, the goals and activities can support the strategic objectives that are assessed by the metrics within the assessment framework. This guidance and call to action may be relevant for departments and programs across the broad spectrum of scientific and engineering research.

Table 2 | Data table for collecting demographic information

Category (collect by gender, ethnic and racial groups)	Fall 2024	Fall 2025	Fall 2026
Undergraduate student enrolment			
Bachelor's degrees conferred			
Master's student enrolment (if applicable)			
Master's degrees conferred (if applicable)			
Doctoral student enrolment (if applicable)			
Doctoral degrees conferred (if applicable)			
Postdoctoral researchers (if applicable)			
Administrative staff			
Technical staff			
Tenured/tenure-track faculty			
Non-tenure-track faculty			

Reporting categories as defined by the National Science Foundation (NSF).

Box 4

Defining diversity

Diversity means that the science, technology, engineering and mathematics (STEM) workforce, including faculty, should reflect and represent the identities of the region of the university or school. For example, Black, African American, Latine (Latino/Latina) and Indigenous individuals comprise only ~8.4% of STEM faculty in the United States but make up 34% of the US population. In addition, stark differences exist along gender lines; the intersectionality of race, ethnicity and gender highlights further disparities, with fewer women represented in the US STEM workforce than men (for example, Black women are less represented than Black men). Other identity groups may also be systemically excluded; however, statistics, including US census statistics, are often not collected beyond gender, race and ethnicity-related identities, and therefore there is a lack of data on diversity with regards to other identities, such as disabled and LGBTQ+ individuals.

Allowing and identifying intersectional identities are crucial, as each marginalization compounds the effects of exclusion. To have appropriate representation of all groups in the professional workforce, each department should thus consider the intended impact and define the goals. For example, for institutions serving their local region, an appropriate goal may be to achieve a representation similar to that of the region. Alternatively, institutions could seek to achieve the diversity of the country. Therefore, the demographics of the region, country and perhaps even continent should be considered in a diversity, equity and inclusion (DEI) plan. Factors to consider in addition to ethnicity and race include gender, disability, LGBTQ+, socioeconomics and immigration status (such as citizenship). Regional diversity may be particularly important for areas such as the European Union, which allows its citizens to work in any country that is part of the Union. If data on the make-up of the local population is unavailable, an important first step is to survey the population and obtain statistics on diversity within the region, which can then be compared to institutional diversity.

Collecting demographic data

Demographics should be regularly collected and reviewed (Table 2). However, demographic data only provide a narrow snapshot of the actual culture and climate of a department or program. Therefore, an iterative strategic plan that incorporates self-reflection and that evaluates the status towards goal achievement must be developed at the department level. Nevertheless, collecting demographic data is crucial to analyse the development of demographics over time. Collection of data on recruitment, retention, recognition and department service, as well as engagement, may provide insight into the longitudinal effects of departmental DEI policies and practices. Data should be collected annually for basic demographics, and surveys with additional demographic and climate information should be performed every other year to avoid survey fatigue. Although more frequent demographic information may be desirable, most actionable information provided by climate surveys will require time to implement and disseminate to change culture.

Goals

A goal is defined as a self-identified and measurable step or benchmark towards achieving broader diversity objectives in the strategic plan. Importantly, benchmarks should reflect those of the geographical location, local community and student populations, recognizing that the most important result is steady improvement rather than achieving a lofty goal (Table 3). For example, professional development workshops designed for women but open to all may improve overall student preparedness for the job search[44].

Implementation and success metrics

Once a goal has been identified, the activity, outcome, necessary resources, person(s) accountable and success metric(s) should be clearly articulated. Walking through each step involves establishing activities and outcomes, determining who is accountable for actions, providing resources, and defining success metrics.

Activities. Activities are actionable events or changes tied to a goal within the plan. These activities can be general, such as annual town halls, or more specific, such as developing inclusive teaching methods within departmental courses (Box 1). For example, one activity to support the goal of profiling diverse engineers may include the identification of persons historically excluded from STEM across different disciplines, connecting these persons with courses taught in the department, providing instructors with examples for a variety of classes, and compiling databases with examples of diverse engineers for shared use across the discipline.

Outcomes. Outcomes are clearly defined expectations upon completion of the activity. The expected outcomes of the example activity above is the development of a departmental database of engineers who are historically excluded; and students will learn about innovation and expertise from diverse perspectives.

Accountable person(s). One or more accountable person(s) should be identified to ensure implementation and execution of the activity. In the example activity above, multiple persons are identified as accountable, including course instructors, undergraduate and graduate coordinators, and the department head.

Resources. Resources are time and/or money. Activities suggested for each goal must have an appropriate budget and personnel time to ensure successful implementation and outcomes. In the example activity above, there is a minimal cost associated with identifying examples of diverse engineers, including faculty and graduate student time and possible student presentations; however, the time allocated to the activity must be appropriate within workload and credit must be given.

Success metrics. Success metrics are benchmarks that indicate success of the goal. For example, a success metric for the activity discussed above could be a count of any scientists or engineers that are highlighted in classes, and whether the percentage of persons historically excluded in STEM who are presented meets or exceeds national demographics.

Assessment

The goals, activities, outcomes and resources may be department-specific; however, the DEI plan must be accompanied by an assessment framework to determine whether activities are leading to broader

Table 3 | Template and examples for components of department-level DEI plans

Immediate goals	Long-term goals
Undergraduate program plan specifics	
Goal: Identify persons who are historically excluded based on ethnicity and/or race[47] in classes, to showcase diversity in the profession. **Activity:** Identify persons across different disciplines; faculty highlight persons in class; compile persons in database. **Outcome:** A departmental database of persons who are historically excluded based on ethnicity and/or race; showcase innovation and expertise led by persons who are historically excluded based on ethnicity and/or race. **Accountable person(s):** Course instructor, undergraduate/graduate chair, department chair. **Resources:** Minimal costs; faculty and graduate student time; student presentations. **Success metrics:** Percentage of persons who are historically excluded based on ethnicity and/or race highlighted in classes meets or exceeds national demographics.	**Goal 1:** Development of new courses; for example demonstrating the effects of systemic racism in medicine and bioengineering research on underserved populations (Tuskegee syphilis study[48], Flint water crisis, Cancer Alley Louisiana). **Goal 2:** Revising course requirements and offerings to provide flexibility through multiple pathways to a 4-year degree. **Goal 3:** Active Louis Stokes Alliance for Minority Participation (LSAMP) programs. **Goal 4:** Alumni mentoring students; use alumni network to build connections and community (may improve retention); for example as group mentors for culminating design projects (for example Northeastern University ChemE mentoring), one-on-one mentors or guest lectures.
Graduate program plan specifics	
Goal: Implement holistic admissions processes. **Activity:** Remove graduate record examination requirements; establish a graduate admission review rubric; increase and adapt recruitment efforts to expand applicant pool. **Outcome:** Uniform review of graduate applicants; increased access for applicants with non-traditional paths and talents. **Accountable person(s):** Graduate chair or director; graduate committee members; department chair. **Resources:** No costs; faculty buy-in. **Success metrics:** Percentage of persons applying meets or exceeds national demographics; percentage of persons accepted to the program meets or exceeds national demographics.	**Goal 1:** Increase graduate stipends to the living wage. Increase can be stepwise or at once; resources needed for implementation must be clearly communicated, and buy-in of the administration will be needed for transitional support; possible sources of funding include transitional overhead return changes. **Goal 2:** Bridge programs for students transitioning from master to PhD institutions; Postbaccalaureate Research Education Program (funded by the National Institutes of Health); society-funded programs to increase preparation for PhD programs. **Goal 3:** Implement peer-mentoring to support graduate student, faculty, postdoc and undergraduate success leading to inclusive environments that foster retention. **Goal 4:** Alter fellowship criteria to reflect holistic review. **Goal 5:** Reduce or eliminate graduate application fees.
Department plan specifics	
Goal: Town hall to discuss department culture and environment. **Activity:** Plan dates and timing; establish Q&A process before and during the event; consider or obtain external moderator. **Outcome:** Baseline knowledge of emerging departmental issues; ideas for future DEI efforts; stakeholders feel heard. **Accountable person(s):** DEI director. **Resources:** Venue; publicity. **Success metrics:** Number of attendees; attended by representatives from students, faculty and staff, including persons who are historically excluded based on ethnicity and/or race; number of actionable items brought to light; number of actionable items resolved to the satisfaction of stakeholders.	**Goal 1:** Expect and recognize DEI-related service (for example as service requirement for merit review and raises). **Goal 2:** Department head evaluating faculty pay equity and issuing off-cycle equity raises to address disparities. **Goal 3:** Highlight diverse members of the department using university news and social media outlets, as well as by nominating members for awards. **Goal 4:** Be intentional about selection to ensure a diversity of seminar speakers that meet desired demographics.

DEI, diversity, equity and inclusion.

departmental or program changes or best practices. For example, monitoring changes in specific categories (Table 2) provides a quantitative method of assessment if the data pool is large enough; thus, assessment metrics should consider sample size and feedback mechanisms so as to not identify individuals. Importantly, change should be monitored and assessed through various means, including surveys, town halls and focus groups.

Climate surveys provide answers to specific questions about the culture and climate of the department; however, this information is typically descriptive, and causation can only be inferred. Considering survey fatigue, care should be taken to develop engaging questions and limit polling frequency. Although surveys provide a means of accessing a broad cross-section of the departmental community, the collected data may be superficial and depend on the community's willingness to respond. A typical survey may include questions about demographics (for example based upon the US Census American Community Survey), inclusion, equity, interactions with others, discrimination, microaggressions, harassment, wellness, community connection and overall satisfaction. Respondents can also be prompted to provide free-form answers about which actions are valuable or which ones could be improved. Sample climate surveys are available freely online from the University of South Carolina, University of Michigan and the Higher Education Data Sharing (HEDS) Consortium.

Town halls are typically in-person interactions with the entire community. These interactions can be informative, depending on the community's overall comfort level and the degree to which attendees may be concerned about sharing information. Concerns can include being identified, a lack of trust in administration to provide answers

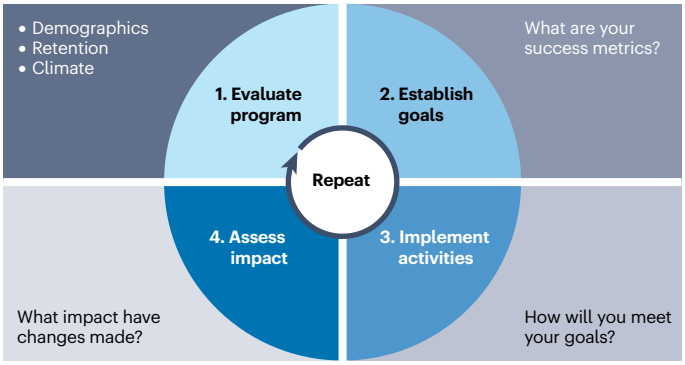

Fig. 2 | Flowchart for developing a diversity, equity and inclusion plan. Important first steps in the process of developing and executing a diversity, equity and inclusion (DEI) plan: evaluate program, establish goals, implement activities, assess impact.

to issues, potential scheduling challenges, potential of a few voices to dominate and unequal power dynamics. Therefore, it is important that the leadership respond to concerns and set ground rules for respectful conversation, as sessions may otherwise devolve into unproductive exchanges of complaints if poorly moderated.

Focus groups are smaller, in-person samplings of community sentiment. For example, a guide on how to use a focus group is available online through the US Department of Defense or the Center for Disease Control. However, determining which constituent group is most likely to attend remains difficult. Importantly, power dynamics can be mitigated by adjusting group make-up. Both focus groups and town halls are useful in gathering insights on specific issues; however, outcomes are typically qualitative and not quantitative. Additional information may be obtained from human resources departments, in addition to social science departments that train students in assessment fields. Where possible, results should be interpreted by social science professionals with experience in survey evaluation. The feedback from the community should be reviewed as part of developing the DEI plan for a department.

Regardless of the climate assessment methods, the community must trust that something will be done and that their responses will be taken seriously by leadership. In return, the leadership must trust that the community will be honest and respectful. The involvement of a third-party moderator from outside the department (for example university-level ombud or DEI director, independent facilitator, or external survey management organization) can help establish community trust in the process. Finally, it is important to 'close the loop' and provide a response to the community as a whole and to those who took the time to respond to surveys or attend events. Furthermore, those who speak up should be credited, concerns should be addressed, and priorities should be defined. Out-of-scope issues may be delegated to those who may be able to address them. This follow-up helps to build trust that actions will occur at the department level.

Outlook

Transformative change does not occur with quick fixes. It requires self-reflection and rethinking the status quo[45]. Creating inclusive and belonging cultures in STEM requires continuous work and effort to listen to historically excluded communities, identify structural barriers (Table 1), and implement activities and policies in academic communities. Educators and scientific innovators owe it to the public to be transparent about the intentional actions they are taking to cultivate the next generation of STEM leaders and contributors.

A DEI scorecard can be used to recognize departments for their efforts towards an inclusive environment. The initial steps towards the goal of improving DEI in STEM can be achieved through accountability of departments who are just beginning their efforts and those departments that have been more intentional about their current efforts. These efforts need leaders. Therefore, we call on department and program leaders to collect and explore the metrics within their departments and sponsor the inclusive development of a plan that identifies priorities in line with available resources, actions and activities, to improve diversity in STEM. For accountability, goals, activities and lessons learned must be publicly available for the department community. Therefore, the plan should be posted on the department website and updated annually.

Departmental and programmatic action and accountability are crucial for effective, lasting impact in diversifying STEM. Thus, we also call on professional societies to lead the way in implementing inclusive cultural practices throughout education and industry. Federal agencies must consider the institutional environment and culture as equal in importance to the available resources and equipment within training and workforce development grants. We further call on higher educational institutions to insist on transparency to support, amplify and provide accountability for efforts to diversify STEM. Without systemic change, we will fail to create the diverse teams of scientists and engineers required to generate innovative solutions to complex bioengineering challenges.

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