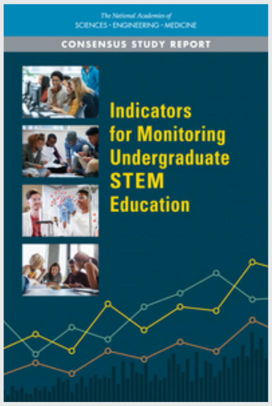

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CONTRIBUTORS

Mark B. Rosenberg, Margaret L. Hilton, and Kenne A. Dibner, Editors; Committee on Developing Indicators for Undergraduate STEM Education; Board on Science Education; Division of Behavioral and Social Sciences and Education; National Academies of Sciences, Engineering, and Medicine

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Indicators for Monitoring Undergraduate STEM Education

Committee on Developing Indicators for Undergraduate STEM Education

Mark B. Rosenberg, Margaret L. Hilton, and Kenne A. Dibner, *Editors*

Board on Science Education

Division of Behavioral and Social Sciences and Education

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Goal 2: Strive for Equity, Diversity, and Inclusion

Equity, diversity, and inclusion are distinct concepts, and all three are critically important to ensuring that the undergraduate STEM educational system meets the nation's needs and serves all people (Witham et al., 2015). For quite some time, there has been ongoing discussion about the compatibility of equity and excellence in STEM education (e.g., Association of American Colleges & Universities, 2015; Gates, 1995; Howard Hughes Medical Institute, 2016; Malcom et al., 1984). There is growing recognition that in order to achieve excellence and effectiveness, the STEM educational system needs to serve all students well (e.g., National Academies of Sciences, Engineering, and Medicine, 2016). Therefore, the committee's second goal is for STEM undergraduate education to be equitable, diverse, and inclusive.

To be considered equitable, institutions and STEM departments would provide enrolled students with adequate support to enter, persist, and successfully complete STEM general education coursework or STEM degrees, by engaging all students in evidence-based STEM educational practices and programs.[1] To be considered diverse, the national pool of students participating and succeeding in undergraduate STEM education would be representative of the demographics of the U.S. college student population. STEM instructors, including faculty and graduate student educators, would also reflect the national pool of individuals eligible to teach in undergraduate STEM education. Finally, to be inclusive, undergraduate STEM learning environments would need to effectively engage and educate diverse learners.

[1] Such practices and programs are detailed in Chapter 3.

The major sections of this chapter address the committee's four objectives for Goal 2:

- Objective 2.1 Equity of access to high-quality undergraduate STEM educational programs and experiences
- Objective 2.2 Representational diversity among STEM credential earners
- Objective 2.3 Representational diversity among STEM instructors
- Objective 2.4 Inclusive environments in institutions and STEM departments

These *objectives* reflect the optimal state of an equitable, diverse, and inclusive undergraduate STEM educational system, and the following sections of this chapter focus on each one. Each section opens by describing the objective and summarizing research demonstrating its importance for improving the quality and impact of undergraduate STEM education. It then proposes *indicators,* which are characteristics that policy makers would observe to monitor progress toward the objective: see Table 4-1. In Appendix B, the committee offers potential measures for each indicator: specific quantitative variables that provide a reliable method for monitoring progress toward achieving the objective.

The numbers of women, minorities, economically disadvantaged people, and people with disabilities who participate and earn bachelor's degrees in STEM fields have grown over the past several decades, though the patterns of growth and participation vary by discipline and subpopulation (National Science Foundation, 2017). Despite this progress, these groups remain underrepresented among STEM degree earners, relative to their representation among the nation's adult population, to the enrolled college student population, and to undergraduate degree earners (National Science Foundation, 2017). As a recent National Academies of Sciences, Engineering, and Medicine (2016) report outlines, the reasons for the continued underrepresentation of women, minorities, people who are economically disadvantaged, and people with disabilities are numerous, complex, and systemic. These factors include disparate levels of exposure to STEM in K–12 schools and communities, unequal access to advanced coursework in middle and high school mathematics and science, stratified patterns of college attendance, unwelcoming disciplinary cultures, and "chilly" departmental climates that do not include diverse role models. Because these factors operate at different points along the pathways to a STEM undergraduate degree, achieving equitable participation and outcomes in STEM requires a multipronged approach, involving new practices, policies, and structures across the educational system (National Academies of Sciences, Engineering, and Medicine, 2016).

TABLE 4-1 Objectives and Indicators of Equity, Diversity, and Inclusion

Objectives	Indicators
2.1 Equity of access to high-quality undergraduate STEM educational programs and experiences	2.1.1 Institutional structures, policies, and practices that strengthen levels of STEM readiness for entering and enrolled college students
	2.1.2 Entrance to and persistence in STEM academic programs
	2.1.3 Equitable student participation in evidence-based STEM educational practices
2.2 Representational diversity among STEM credential earners	2.2.1 Diversity of STEM degree and certificate earners in comparison with diversity of degree and certificate earners in all fields
	2.2.2 Diversity of students who transfer from 2- to 4-year STEM programs in comparison with diversity of students in 2-year STEM programs
	2.2.3 Time to degree for students in STEM academic programs
2.3 Representational diversity among STEM instructors	2.3.1 Diversity of STEM instructors in comparison with diversity of STEM graduate degree holders
	2.3.2 Diversity of STEM graduate student instructors in comparison with diversity of STEM graduate students
2.4 Inclusive environments in institutions and STEM departments	2.4.1 Students pursuing STEM credentials feel included and supported in their academic programs and departments
	2.4.2 Instructors teaching courses in STEM disciplines feel supported and included within their departments
	2.4.3 Institutional practices are culturally responsive, inclusive, and consistent across the institution

OBJECTIVE 2.1: EQUITY OF ACCESS TO HIGH-QUALITY UNDERGRADUATE STEM EDUCATIONAL PROGRAMS AND EXPERIENCES

Importance of the Objective

Advancing the nation's STEM education system and workforce is a goal shared by many of the nation's leading scientific societies, higher education associations, and science-related federal agencies. Within the past several years, reports from the American Association for the Advancement of Science (2011, 2015), the Obama Administration's President Council of Advisors on Science and Technology [PCAST] (2012), the Howard Hughes Medical Institute (2016), and the Association of American Colleges & Universities (Elrod and Kezar, 2015, 2016) have emphasized the need to broaden participation in STEM disciplines and increase STEM degree completion. To achieve these aims, these organizations recommend that 2-year and 4-year colleges and universities engage all students in STEM fields by offering high-quality learning experiences with adequate academic and institutional support to succeed in key introductory and gateway science and mathematics courses (see also National Academies of Sciences, Engineering, and Medicine, 2016). These reports on the shared goal of broadening participation in STEM disciplines and increasing STEM degree completion call for widespread implementation of new teaching, learning, and student support programs that have been shown by research to enhance student learning and persistence.

In developing indicators of the status of this objective, the committee responded to its charge to focus on the U.S. undergraduate STEM education system, rather than the inputs into this system (such as the K–12 system that prepares entering undergraduates). Hence, rather than proposing indicators of students' STEM readiness upon high school exit (e.g., standardized test scores, high school mathematics and science course taking patterns, etc.), the committee focused on institutional practices that improve enrolled college students' STEM readiness, students' STEM-related experiences, and students' progression through key educational milestones that lead to STEM degree completion.

The committee's approach was similar to that of an earlier report that proposed indicators for monitoring the capacity of the nation's K–12 educational system to advance the goals of expanding the number of STEM degree seekers and enriching the STEM-capable workforce (National Research Council, 2013). In addition to student outcomes, the indicator system proposed by that prior committee included measures of schooling environments, policies, and practices that have been demonstrated to be effective in advancing the aforementioned goals. Similarly, the committee's proposed indicators for this objective relate to institutional environments, policies, and practices that have a demonstrably positive effect on student entrance into, persistence within and completion of STEM degree programs.

Proposed Indicators

Indicator 2.1.1: Institutional Structures, Policies, and Practices That Strengthen STEM Readiness for Entering and Enrolled College Students

The share of first-year students at 4-year colleges and universities indicating an intention to major in STEM fields grew from about one-third in 2007 to 45 percent in 2014 (National Science Foundation, 2016). However, the share of all bachelor's degrees awarded in STEM fields has stayed steady at about one-third (National Science Foundation, 2016). There is no single cause of the gap between student intentions and outcomes in STEM, but research shows that students who change their initial intentions to pursue STEM bachelor's degrees switch out of these degree fields after their experiences in introductory mathematics and science coursework (National Academies of Sciences, Engineering, and Medicine, 2016). Moreover, although historically underrepresented populations report their intentions to pursue STEM bachelor's degrees at rates that are comparable to or slightly below the average for all students (National Science Foundation, 2017), STEM degree completion rates for Black, Hispanic, and Native American students fall far below those for Asians and whites (National Academies of Sciences, Engineering, and Medicine, 2016). Previous research (e.g., Estrada, 2014) has identified critical forms of student support and co-curricular educational practices that institutions can put into place to smooth the pathways to STEM degree completion for a range of student populations, particularly those students who are underrepresented in STEM fields.

Following the recommendations in a previous report of the National Academies of Sciences, Engineering, and Medicine (2016), the committee underscores the need for institutions to take active steps to ensure equitable access to evidence-based STEM educational practices—even in the face of inequities in STEM preparedness among admitted and enrolled students. The proposed indicator above would provide information about the prevalence of institutional and instructional programs and practices that are designed to strengthen students' competencies and skills that are foundational to success in STEM undergraduate degree programs. The focus of these programs and practices might be mathematics, writing, or critical thinking or they might be intended to provide students with the navigational and academic skills necessary to succeed in college.

Depending on the type of institution, these programs and practices may take the form of dual enrollment programs (An, 2013; Blankenberger, Lichtenberger, and Witt, 2017; Speroni, 2011), bridge programs (Gilmer, 2007; Lenaburg et al., 2012), accelerated curriculum for developmental mathematics (Rutschow and Diamond, 2015), and the use of guided pathways (Bailey, Jaggars, and Jenkins, 2015; Baker, 2016). These examples are just starting points, but they reflect the type of programs and practices that have been implemented across a range of postsecondary institutional types, selectivity, and mission. Such programs and practices have been shown to support diverse students who have been admitted to college with gaps in their STEM-related knowledge (Lenaburg et al., 2012; Baker, 2016; Gilmer, 2007; Rutschow and Diamond, 2015; Speroni, 2011). Thus, these institutional supports can create more equitable conditions that help students to begin and succeed in STEM fields.

The committee recognizes that institutions vary in size and resources and thus in their capacity to offer such programs and practices, as well as in the number of students they can serve with these programs and practices. For this reason, it is important to disaggregate the specific measures of Indicator 2.1.1 by type of 2-year or 4-year institution (e.g., research university, liberal arts college, for-profit or nonprofit 2-year college), special mission status (i.e., minority-serving institution), selectivity, and size.

Indicator 2.1.2: Entrance to and Persistence in STEM Academic Programs

Students of color, women, low-income students, and first-generation students are less likely to enter and persist in undergraduate STEM educational programs than other students, further contributing to inequities in STEM degree completion (National Science Foundation, 2017). And although women, men, students of color, and white students, on average, switch out of STEM degree programs to non-STEM programs at similar rates, equity gaps in persistence rates exist within certain STEM disciplines and at highly selective institutions (Chen, 2013). These differences in persistence act to worsen disparate levels of access to critical STEM learning experiences that might occur with advanced-level coursework (e.g., junior laboratory, capstone experiences, senior design courses). Given the importance of entrance to and persistence in STEM undergraduate degree programs to advancing the goal of equity and diversity in undergraduate STEM education, this indicator would consist of multiple measures of student entry and persistence in STEM majors, disaggregated by race and ethnicity, gender, socioeconomic status, ability status, and STEM discipline.

The committee notes that this indicator overlaps with Indicator 3.2.1 on course-to-course and year-to-year retention in STEM programs (see Chapter 5), but that one focuses on overall persistence in STEM; this one would break down the overall persistence trends, illuminating the trends in persistence of different demographic groups.

Developing and maintaining high levels of interest in STEM for all entering college students are necessary conditions for advancing equity and diversity in undergraduate STEM education. While first-year college students likely develop such interest over the course of their precollege educational experiences, colleges and universities also play a role in promoting and maintaining their interest in pursuing STEM degrees. For example, institutions may be able to bolster interest in STEM among first-year students by providing early exposure to the range of STEM program offerings, offering opportunities for career exploration, and providing both entering and first-year students with individualized advising and degree planning (see discussion of advising and mentoring in Chapter 3).

Achieving greater equity and diversity in undergraduate STEM education also requires that students who express an interest in STEM early in their college experiences actually enter into and persist in STEM degree programs. Indicator 2.1.2 (above) also includes measures of student persistence—the extent to which students who enter into a STEM degree program maintain enrollment in that program. Again, disaggregating by key student characteristics and STEM discipline would indicate whether certain student populations are more likely to leave STEM fields than others.

Indicator 2.1.3: Equitable Student Participation in Evidence-Based STEM Educational Practices and Programs

Evidence-based STEM educational practices and programs can take many forms and can be provided inside or outside the classroom. Inside the classroom, discipline-based education research has deepened our understanding of teaching approaches that improve student learning within and across STEM disciplines (National Research Council, 2012). These evidence-based teaching practices have been shown to increase students' mastery of STEM concepts and skills. They include interactive lectures, collaborative learning activities, lecture-tutorial approaches, and laboratory experiences that incorporate realistic scientific practices and the use of technology (National Research Council, 2012).

At the same time, research has begun to show that programs outside the classroom—such as undergraduate research experiences, internships, and summer bridge programs—can support students' learning, identification with STEM, and persistence in STEM programs (National Academies of Sciences, Engineering, and Medicine, 2016, 2017). For example, studies of STEM majors found that participating in STEM-specific programs enriched their understanding of how STEM content is related to real-world applications (e.g., Estrada, 2014). When implemented well, such programs can provide valuable learning experiences for students, potentially boosting their interest in STEM fields, strengthening their STEM identities, and cultivating graduate school aspirations (Eagan et al., 2013). There is also some evidence that these educational practices and programs are particularly effective in increasing learning and retention among historically underrepresented students in STEM, making access to and participation in such practices vital to advancing equity in STEM outcomes and degree attainment.

This indicator would provide information about the patterns of access to and participation in evidence-based STEM educational practices and co-curricular programs. It would be disaggregated across student demographic groups (race and ethnicity, gender, socioeconomic status and ability status), institutional type (e.g., research university, liberal arts college, 2-year college), and STEM discipline. Students' engagement in such practices and programs has been shown to promote mastery of STEM concepts and skills and retention in STEM majors (e.g., National Research Council, 2012). In addition, there is growing evidence that participation in certain evidence-based programs outside the classroom (e.g., undergraduate research, mentoring, bridge programs) can boost STEM retention and career and graduate school aspirations (Eagan et al., 2013; Estrada, 2014; Gilmer, 2007; Lenaburg et al., 2012; Packard, 2016). For example, a recent review of research related to undergraduate research experiences (National Academies of Sciences, Engineering, and Medicine, 2017) concluded that participation in this type of evidence-based educational practice is beneficial for all students and, for students from historically underrepresented groups, improves their persistence in STEM and helps to validate their disciplinary identity.

Only limited research is available on the extent to which different student groups participate in these valuable evidence-based educational practices. For example, data from the National Survey of Student Engagement (NSSE) indicate that certain student groups that are historically underrepresented in STEM fields, including Blacks, Hispanics, Native Americans, low-income students, and first-generation students, are less likely than other students to participate in undergraduate research and five other high-impact practices, though these data do not provide insight into the patterns of participation specifically for STEM majors[2] (Finley and McNair, 2013; National Survey of Student Engagement, 2016). However, the recent National Academies (2017) study of undergraduate research experiences found that data on who participates in these experiences overall or at specific types of institutions have not been collected systematically, and recommended that institutions collect those data.

[2] As discussed in Chapter 3, these high-impact practices are not STEM-specific.

Research is needed to characterize differences among student groups on the effects of engaging in evidence-based STEM educational practices and programs, as well as to identify the mechanisms by which such practices increase retention in STEM degree programs (National Research Council, 2012; National Academies of Sciences, Engineering, and Medicine, 2017). This proposed indicator would facilitate such research, tracking group differences in participation in evidence-based educational practices and programs.

OBJECTIVE 2.2: REPRESENTATIONAL DIVERSITY AMONG STEM CREDENTIAL EARNERS

Importance of the Objective

Expanded access to higher education generally, coupled with targeted efforts to broaden participation in STEM fields, has led to larger numbers of women, minorities, and other historically underserved populations earning STEM degrees. However, the total number of undergraduate credentials earned by these populations in all fields grew at a faster rate. Thus, the proportion of STEM degrees earned by some of these underrepresented groups has not increased—and has even gone down in certain STEM disciplines. Trend data on the diversity of STEM degree earners reflects the "declining equity" of U.S. higher education, whereby inequities experienced by race and ethnicity and economically disadvantaged students are actually worsening, despite overall increases in college attendance (Astin and Oseguera, 2004; Malcom-Piqueux and Malcom, 2013). If students from historically underrepresented groups entered and completed STEM degree programs at the same rate as their white, male counterparts in these programs, then we would expect that STEM degree earners would reflect the diversity of all college degree earners.

Outcome equity is defined as having reached parity in key educational milestones and outcomes (e.g., declaring a STEM major or earning STEM degrees). In other words, if a particular demographic group represents *x* percent of some base population and also earns *x* percent of STEM bachelor's degrees, that group has achieved outcome equity. If the demographic breakdown of STEM degree earners mirrors the demographic breakdown of an appropriate base population, it can be said that the undergraduate STEM education system has achieved representational diversity among STEM degree earners. Though outcome equity focuses only on the outputs of the educational system, reaching representational diversity among STEM credential earners is an indication that institutional practices, policies, and structures are functioning as they should to serve all student populations well.

Proposed Indicators

Indicator 2.2.1: Diversity of STEM Degree and Certificate Earners in Comparison with Diversity of Undergraduate Degree and Certificate Earners in All Fields

This proposed indicator would compare the demographic make-up of students who earned a STEM undergraduate credential within a given time period to the demographic composition of the total number of students who earned an undergraduate credential in any field during that same time period. Both groups would be disaggregated by race and ethnicity, gender, socioeconomic status, and ability status. The committee identified undergraduate degree and certificate earners in all fields as the appropriate population for comparison with STEM undergraduate degree and credential earners. Other comparisons are possible (e.g., diversity of STEM degree holders compared with the diversity of the U.S. adult population); however, the committee selected all credential earners because these individuals were able to successfully navigate higher education environment to complete their degree or certificate programs.

Though the indicator would be reported at the national level, it would be vitally important to disaggregate the related measures by institutional type (e.g., research university, liberal arts college, 2-year institution) and special status (e.g., minority-serving institution). The committee recognizes that because of long-standing inequities in college access and enrollment, achieving equity in STEM degree attainment will require that viable pathways to STEM be established across a broad range of institutions, including 2-year institutions and minority-serving institutions (National Academies of Sciences, Engineering, and Medicine, 2016). The nation's higher education system is highly stratified, with Blacks, Hispanics, economically disadvantaged students, and first-generation college students more likely than other students to attend 2-year institutions and broad-access 4-year institutions (Van Noy and Zeidenberg, 2014). These institutions tend to be under-resourced, offering fewer STEM degree programs and lacking the instructional and research capacity found at more selective doctoral-granting and research universities. As a result, historically underrepresented students tend to experience lower levels of access to undergraduate STEM degrees, particularly in emergent fields.

Group differences in students' academic preparation for success in STEM fields reflect a complex array of factors that operate at the individual, disciplinary, departmental, institutional, and systemic levels (National Academies of Sciences, Engineering, and Medicine, 2016; National Science Foundation, 2017; Malcom-Piqueux and Malcom, 2013). Thus, the committee understands that the patterns of STEM credential attainment may not exactly mirror the patterns from non-STEM fields, which provide the comparison group in this indicator. Nevertheless, the presence of large equity gaps in STEM degree attainment at the national level would indicate that the undergraduate STEM education system is not functioning as intended and is failing to meet the needs of all students.

The committee notes that comparisons with other base populations (e.g., all college students, national adult population) may also be informative. For example, a recent report on the status of women, minorities, and persons with disabilities in science and engineering (National Science Foundation, 2017) presents data on the proportion of STEM degrees earned by historically underrepresented populations along with the demographic breakdown of the U.S. noninstitutionalized adult population. Using this broader base population as the comparison group shows larger equity gaps because of the compounding of inequalities in the rates of high school completion, college entrance, and entry to STEM degree programs experienced by historically underrepresented populations. In order to ensure that any inequities identified from the committee's proposed indicator are attributable only to the undergraduate STEM educational system, our proposed comparison group is all undergraduate degree and certificate earners.

Indicator 2.2.2: Diversity of Students Who Transfer from 2-Year to 4-Year STEM Programs in Comparison with Diversity of Students in 2-Year STEM Programs

The nation's 2-year institutions play an increasingly important role in educating and preparing the nation's STEM workforce (American Association of Community Colleges, 2014; National Science Foundation, 2017; Wang, 2015). Many certificate and associate degree programs in STEM-related technical areas (e.g., aerospace, nuclear technology) lead to high-paying jobs in high-demand fields (American Association of Community Colleges, 2014). In addition to awarding valuable sub-baccalaureate credentials to a diverse range of students, 2-year institutions also act as a pathway to the bachelor's degree through student transfers. Though national data cannot fully characterize the exact role that 2-year institutions play in the educational experiences of STEM bachelor's degree earners (see Bahr et al., 2016; Wang, 2013), nearly half of STEM bachelor's degree holders attended a 2-year institution at some point in their educational careers (Mooney and Foley, 2011).

Indeed, recent analyses (National Academies of Sciences, Engineering, and Medicine, 2016) find that students who earn STEM credentials follow complicated educational trajectories. Attending multiple institutions, reverse transfers, lateral transfers, and concurrent enrollment are increasingly common college attendance patterns among STEM credential earners. Transferring from 2-year to 4-year institutions has great potential for increasing the representation of women, minorities, economically disadvantaged students, and persons with disabilities among STEM bachelor's degree holders due to the high proportion of these populations enrolled in 2-year institutions (Bragg, 2012; Wang, 2015). More than 40 percent of all undergraduate students are enrolled in 2-year institutions, and the percentage is even higher among minorities, first-generation, and low-income populations (National Center for Education Statistics, 2016).

Policy makers can use this proposed indicator to monitor whether historically underrepresented students, who are more likely to begin postsecondary education in 2-year institutions, have equitable access to pathways to STEM bachelor's degrees. In particular, this indicator would identify the extent to which the representation of women, minorities, low-income students, and students with disabilities among students at 2-year institutions who transfer to STEM bachelor's degree programs mirrors their representation among all students enrolled in 2-year STEM programs.

Certainly, not all students who enter 2-year institutions plan or seek to transfer. As mentioned above, many certificate and associate's degree earners in STEM-related technical areas are highly employable, with earnings exceeding bachelor's degree holders in some fields. However, the underrepresentation of women, minorities, low-income students, and students with disabilities among students transferring to STEM bachelor's degree programs in comparison with their share of enrollment in 2-year STEM programs may indicate that these students are experiencing unique barriers to successful transfer that need to be better understood and mitigated through institutional policies and programs.

This indicator is related to an indicator under Goal 3: Transfer between STEM programs (see Chapter 5). The indicator here compares the diversity of students who transfer from 2-year to 4-year STEM programs to the diversity of students enrolled in 2-year STEM programs; the indicator under Goal 3 (3.2.2) compares the diversity of students transferring from 2-year to 4-year STEM programs with the diversity of students transferring into all 4-year programs. For both indicators, it would be valuable to have the information disaggregated by institutional type and a range of demographic characteristics. Monitoring this Indicator 2.2.2 will inform policy makers and practitioners about whether historically underrepresented populations enjoy equitable access to transfer pathways from the 2-year institution to STEM bachelor's degree programs.

Indicator 2.2.3: Time to Degree for Students in STEM Academic Programs

In addition to degree completion, time to degree is also an important indicator of success among STEM majors. The majority of entering college students who intend to pursue STEM bachelor's degrees do not complete them within 4 years (Eagan et al., 2014). In addition to switching out of STEM degree programs entirely, many STEM aspirants attend multiple institutions and stop out or drop out of college (Eagan et al., 2014). Attendance patterns and time to degree vary, based on students' pathways into college, STEM discipline, degree-granting institutional type, and student characteristics. For example, it is not surprising that STEM majors who attend multiple institutions take longer to complete their degrees than those who do not (Salzman and Van Noy, 2014). Similarly, students who decide to major in STEM after the first semester or first year in college experience longer time to degree than those who begin as STEM majors. Among STEM bachelor's degree earners, women and students who are minorities at predominantly white institutions take longer to complete their degrees than do their male, white, and Asian counterparts, respectively (Eagan et al., 2014). These differences in time-to-degree may be attributable to a number of factors, including differences in the pathways that historically underrepresented populations take into and through STEM degree programs and differences in academic preparation at college entry. Thus, extended time-to-degree could indicate success in efforts to diversify the population of STEM graduates.

However, gender, racial, and socioeconomic differences in time-to-degree among STEM graduates may also be further disadvantaging students who already experience inequities in STEM educational outcomes. Though taking longer than 4 years to complete a STEM degree is not inherently problematic, there are potential drawbacks. Students who take longer to complete their degrees have to pay college tuition beyond the 4 years that they may have originally anticipated. If these students exhaust their eligibility for Pell grants or other financial aid, they may have no choice but to accumulate high student debt burdens, work to cover college costs (which will likely further delay STEM degree completion), or leave college altogether (National Academies of Sciences, Engineering, and Medicine, 2016). In addition, there are opportunity costs (i.e., foregone earnings) associated with taking longer to complete a degree. Thus, this indicator will permit the monitoring of the median time-to-degree across a range of STEM degree programs, disaggregated by race and ethnicity, gender, socioeconomic status, and disability status.

OBJECTIVE 2.3: REPRESENTATIONAL DIVERSITY AMONG STEM INSTRUCTORS

Importance of the Objective

Research shows that one effective mechanism by which to address issues of equity and diversity in undergraduate education is to cultivate and retain a diverse cadre of instructors, including tenured and tenure-track faculty, adjunct and part-time instructors, and graduate student instructors. Instructor diversity provides educational benefits to all students and particularly for students of color (Antonio, 2002; Hurtado, 2001; Hurtado et al., 2012; Ibarra, 2001; Marin, 2000; Milem, 2001, 2003; Milem, Chang, and Antonio, 2005; Smith, 2015; Umbach, 2006).

The committee uses the word "representational" in this objective purposefully: ultimately, the diversity of instructors should reflect or represent the ethnic and racial diversity of U.S. society as a whole, given that the benefits of instructor diversity are clearly demonstrated by available research. The committee's indicators, proposed below, would help to gauge the presence of diverse faculty at the national level as a first step toward achieving the objective. Student perceptions of campus and departmental climate are critical to the success of students of color. Evidence consistently shows that when students of color perceive their campus to be racially diverse and inclusive, those students perform better academically (Gurin et al., 2002; Hurtado et al., 2012; Smith, 2015). Research also shows that racially and ethnically diverse campuses support *all* students' intellectual development by increasing students' learning outcomes (Gurin et al., 2002), enhancing critical thinking (Bowman, 2010), and improving intellectual self-concept (Cole, 2007) and civic engagement (Bowman, 2011). Since faculty diversity is one major signal of inclusive and diverse campus climates, maintaining sufficiently diverse faculty members can be seen as one way to support improved outcomes for all students.

Proposed Indicators

Although instructor diversity is a concern across all fields, the representation of historically underrepresented groups among STEM instructors is even lower than overall levels. Thus, the committee proposes the following two indicators that can be used to monitor progress toward representational diversity among STEM instructors. The first indicator focuses on faculty, whether tenured, untenured, adjunct, full time or part time. The second focuses on graduate student instructors. We present them together, and the discussion that follows covers both.

Indicator 2.3.1: Diversity of STEM Instructors in Comparison with Diversity of STEM Graduate Degree Holders

Indicator 2.3.2: Diversity of STEM Graduate Student Instructors in Comparison with Diversity of STEM Graduate Students

Both of these indicators would allow policy makers to monitor the extent to which the diversity of STEM instructors (in terms of gender, race and ethnicity, socioeconomic status, and disability status) reflects the diversity of current STEM graduate degree holders and graduate students, respectively. This framing is intended to reflect what is reasonable to expect from the field: it is unlikely that the diversity of STEM faculty would ever exceed the diversity of STEM graduate degree holders, as a graduate degree is a precursor to faculty status. By measuring the diversity of STEM faculty members as compared to the entire pool of potential STEM faculty members (represented here by STEM graduate degree holders) these indicators are intended to measure progress toward the objective of representational diversity among STEM educators.

The first indicator would need to be disaggregated by institutional type, as well as STEM discipline and instructors' demographic characteristics, due to the differences in degree requirements to hold a faculty position. Many 2-year institutions and some 4-year institutions require only a master's degree to be hired as an instructor, while research institutions will only hire doctorate holders for faculty positions. As a result, we note the importance of carefully defining the comparison groups to construct Indicator 2.3.1.

The second indicator would also require careful disaggregation and interpretation. Data from the National Science Foundation, (2017, Tbl. 7-26) illustrate that in some STEM disciplines (i.e., physical sciences, computer science), historically underrepresented minority doctorate recipients are more likely than their white counterparts to have received their primary support for their studies from teaching assistantships rather than research assistantships. In other STEM disciplines (i.e., agricultural sciences, computer science) women of all races and ethnicities are more likely than their male counterparts to serve as teaching assistants. Given the importance of research experience and publications to moving into STEM faculty careers at many institutions, significant *overrepresentation* of students of color or women among STEM graduate educators may be indicative of other equity challenges.

These indicators only measure the current state of affairs of diversity in STEM. We recognize the tautological limitation of this framing: if currently underrepresented student groups remain underrepresented in STEM, the same lackluster representation will remain in the degree-holding population. Currently, the diversity of STEM faculty does not reflect the diversity of STEM graduate degree holders. We propose that these indicators will allow for monitoring change in the diversity of STEM educators.

OBJECTIVE 2.4: INCLUSIVE ENVIRONMENTS IN INSTITUTIONS AND STEM DEPARTMENTS

Importance of the Objective

Inclusive campus environments are those that focus on students' intellectual development, develop and use organizational resources to enhance student learning in purposeful ways, pay attention to and value the cultural differences that learners bring to educational experiences, and are welcoming communities that engage diversity in the service of student and organizational learning (Williams, Berger, and McClendon, 2005). In short, an inclusive campus environment integrates diversity and equity into the core mission of the institution (Witham et al., 2015).

Cultivating inclusive, supportive learning environments in which all students and instructors can learn and work may help catalyze and sustain institutional and national progress toward achieving greater diversity and equity in undergraduate STEM education. Underrepresented minority students in STEM who experience negative racial experiences in their first 2 years also tend to report a lower sense of belonging to their institution (Hurtado et al., 2007). Similarly, as first-year students majoring in science more frequently encounter a negative racial climate on campus, their likelihood of persisting in those same science majors significantly drops (Chang et al., 2009). Hurtado and colleagues (2012) provide a comprehensive review of empirical studies of campus climate, and the evidence overwhelmingly shows that minority students tend to encounter a more hostile environment on college campuses than other students. These students often feel more disconnected from their institution and tend to report lower scores on critical affective (e.g., self-efficacy) and cognitive outcomes (e.g., grades, degree completion).

Climate is also manifested more locally in departments and academic programs. Environments that encourage unhealthy competition among students may reduce opportunities for group work and collaborative study among students. Gasiewski and colleagues (2012) found that students enrolled in introductory STEM courses felt less inclined to work with their peers when instructors applied norm-referenced (curved) grading strategies in which students' grades depend on their performance relative to their peers. Similarly, students' perceptions of departmental climates may be influenced by instructors' pedagogical strategies (e.g., lecture or group work) or by the ways in which instructors signal their openness to and accessibility for engaging with students inside and outside the classroom (Gasiewski et al., 2012).

Instructors' perceptions of their departmental and institutional climates may affect their willingness to experiment with enhancing their teaching strategies, engagement with colleagues and students, and likelihood to want to continue working at their current institution. Certain groups of instructors—primarily women and minorities—report higher levels of stress due to discrimination or more hostile climates on campus (Turner and González, 2011). These factors tend to reduce overall job satisfaction (Sanderson, Phua, and Herda, 2000) and thus increase the chances of their leaving their academic appointments (Ponjuan, 2006; Rosser, 2004).

Proposed Indicators

Because the first two indicators of this objective are closely related, they are presented together, and the discussion that follows covers both.

Indicator 2.4.1: Students Pursuing STEM Credentials Feel Included and Supported in Their Academic Programs and Departments

Indicator 2.4.2: Instructors Teaching Courses in STEM Disciplines Feel Included and Supported in Their Departments

STEM students' and instructors' experiences with supportive and inclusive campus and departmental climates likely serve as leading indicators of whether progress is being made toward the objectives of representational diversity among STEM credential earners and STEM instructors. Perceptions about one's environment are inherently personal, but when these views are aggregated across representative samples of students and faculty, one can make inferences about the overall nature of inclusion and support. The first indicator above would gauge how positively STEM students feel about their academic departments and/or institutional environments; the second would do the same for instructors. For both indicators, it is critical that data are disaggregated by race and ethnicity, gender, disability status, discipline, and institutional type in order to determine whether the sense of inclusion and support differ along these dimensions.

Indicator 2.4.3: Institutional Practices Are Culturally Responsive, Inclusive, and Consistent Across the Institution

This indicator is intended to measure the policies and practices of institutions, and STEM departments, including support programs, and co-curricular activities that contribute to and cultivate climates that are diverse, inclusive, and equitable. Such practices and policies include those that aim to engage diverse learners in and outside of STEM classrooms in order to produce more equitable outcomes. Though related to the indicator above on institutional structures, policies, and practices that strengthen levels of STEM readiness for entering college students (Indicator 2.1.1), this indicator is distinct because it focuses on the experiences of students enrolled in STEM academic programs, not on practices intended to increase student readiness for such programs.

Students who are historically underrepresented in STEM fields often face unique challenges (stereotypes, stereotype threat, implicit bias) that negatively affect their ability to enter, persist, and succeed in STEM fields (Fries-Britt and Griffin, 2007; Godsil, 2016; Martin, 2009; McGee and Martin, 2011). Culturally responsive pedagogies and instructional approaches include those that are interactive, asset-based, and focus on building student identities. These practices and approaches have been demonstrated to build more equitable learning environments in some educational contexts (Gay, 2000; Ladson-Billings, 1995; Moses et al., 1989; Nasir et al., 2014; Paris, 2012), but they have not been widely implemented in STEM at the postsecondary level (Davis, Hauk, and Latiolais, 2009). For example, most mathematics classrooms use standard lecture formats (Eagan, 2016). Though additional research is needed, a growing evidence base suggests that developing diverse students' sense of belonging and improving student-faculty interactions is conducive to broadening participation in STEM fields. The committee envisions that this indicator would allow for the monitoring of data about the prevalence of culturally responsive educational approaches used in STEM departments. Recruiting and retaining a diverse STEM faculty is also critical to inclusive educational environments (as discussed above). Thus, the indicator would include measures about the use of search and hiring practices that are effective in diversifying STEM faculty (e.g., implicit bias training).

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