

*Perspective:*

# THE STEALTH OF IMPLICIT BIAS IN CHEMICAL ENGINEERING EDUCATION, ITS THREAT TO DIVERSITY, AND WHAT PROFESSORS CAN DO TO PROMOTE AN INCLUSIVE FUTURE

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It is well established that there is a critical need to diversify and grow the STEM workforce to remain competitive in a global economy. Recognizing the need to attract and retain the most talented individuals to STEM professions, the National Academies advocate that diversity in STEM must be a national priority.<sup>[1]</sup> Research suggests that improving diversity in a workforce has positive effects on creativity, innovation, productivity, and financial performance.<sup>[2-4]</sup> Further, growing interest in, engagement with, and retention of more students through engineering programs is necessary to meet domestic workforce demands in the foreseeable future.<sup>[5]</sup>

The benefits of diversity extend to the educational environment. There is compelling evidence that diversity among students and faculty is crucially important to the intellectual and social development of all students, and failure to create an inclusive environment for minority students negatively affects both minority and majority students.<sup>[6-8]</sup> How students experience their campus environment impacts both learning and developmental outcomes.<sup>[9,10]</sup> In addition, environments in which students experience harassment or discrimination hinder student learning,<sup>[9,11-14]</sup> and the culture of STEM education negatively affects students' interest, self-concept, sense of belonging, and persistence in technical disciplines.<sup>[15]</sup>

The American Institute of Chemical Engineers recognizes explicitly the importance of diversity in the profession through its *Mission Statement*, *Code of Ethics*, and *Diversity Statement*. In its Mission, AIChE pledges to "Uphold and advance the profession's standards, ethics and diversity."<sup>[16]</sup> According to AIChE's *Code of Ethics*, members will "treat all colleagues

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and co-workers fairly and respectfully, recognizing their unique contributions and capabilities by fostering an environment of equity, diversity, and inclusion.” In November 2015, the board of directors approved the Institute’s *Diversity Statement*, which proclaims AIChE’s commitment to “creating an environment in the Institute and profession in which all members, regardless of characteristics such as gender, race, religion, age, physical condition, sexual orientation, nationality, or ethnicity, are valued and respected.”<sup>[17]</sup> The mere fact that these statements need to be made so explicitly points to the historical prevalence of members encountering the exclusions listed. Thus, there exists a need for chemical engineering professors to re-examine their own, their department’s, and our field’s standard practices with an enlightened lens to rethink which habits and practices communicate exclusion.

While diversity traditionally has focused on increasing representation of historically underrepresented groups (women and racial/ethnic minorities in STEM), other dimensions of diversity deserve serious attention,<sup>[18]</sup> for example, socioeconomic status, religious belief, veteran status, ability, age, and sexual orientation. Inclusion refers to active and intentional engagement with all dimensions of diversity<sup>[19]</sup> and building an environment in which everyone has the opportunity to reach their full potential (Thomas, 1990 in Reference 20). In an inclusive work culture, the uniqueness of individual differences and the value of group and social differences are welcomed, respected, and valued by members of the organization. Research by Bendick Jr.<sup>[21]</sup> showed that a lack of diversity in an organization is a symptom, and its cause is a lack of inclusion. Lack of inclusion is known to have a negative impact in STEM education—one of the key reasons cited for students leaving STEM is the perception of a chilly climate, especially by those who are members of underrepresented groups.<sup>[22]</sup>

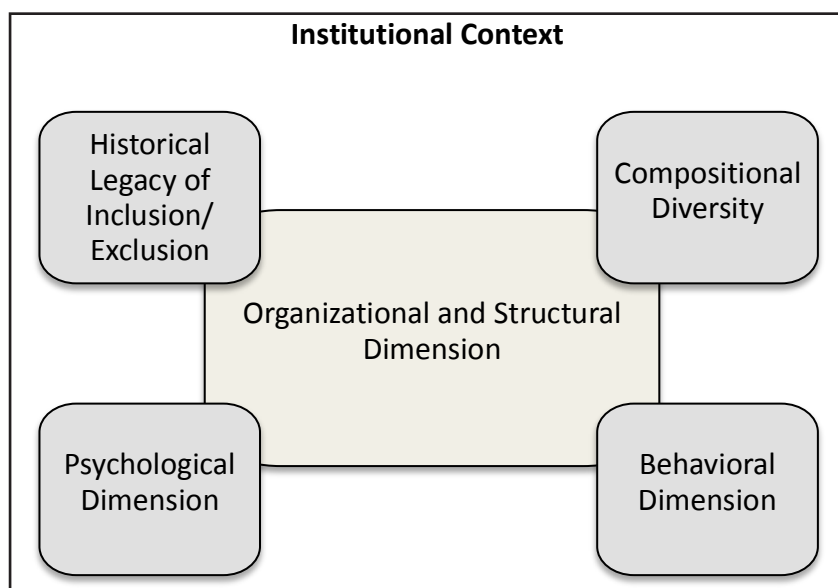
Diversity and inclusion on campuses are multidimensional and complex. Milem<sup>[11]</sup> presents a framework for campus climate in which institutional context has five interconnected

dimensions as shown in Figure 1. The organizational/structural dimension represents ways in which benefits for some groups are embedded into the structural practices and policies of the institution such as decision-making, admissions practices, hiring practices, reward systems, and curriculum. The history of exclusion on campuses is longer than the history of inclusion, and the historical legacy dimension considers how this tradition shapes the present dynamics on campus. The psychological climate includes the views and attitudes held by individuals about engaging with diversity, perceptions of bias (both implicit and explicit) and discrimination, and institutional responses to diversity. The behavioral dimension refers to the nature of interactions among diverse individuals and groups. Compositional diversity refers to student enrollment and faculty/staff hiring, and maintaining compositional diversity requires intentional engagement with all dimensions of diversity in the framework for campus climate. The adhesive between these dimensions of diversity and inclusion are the individuals and leaders on the campus. The shared governance structure of most academic institutions provides

professors considerable influence both with students and with the campus climate.

Given this framework, what role does a chemical engineering professor—or any engineering educator—serve in preparing the next generation of engineering professionals to be equipped to thrive in diverse and inclusive workplaces? Are we transmitters of knowledge, facilitators of learning, gatekeepers to quality, assessors, judges of what counts as engineering, or some combination of the above? In these roles, educators effectively decide who is good enough to enter the chemical engineering profession. Many educators hold fairness and egalitarianism as core values that we strive to uphold in our professional work and personal lives, and we hope that we evaluate and support students based strictly on student potential and achievement.

However, everyone holds unconscious beliefs about social and identity groups. Conscious thought is estimated to account



**Figure 1.** Institutional context within the framework for Campus Climate (adapted from Reference 11).

for only about 10% of brain capacity; subconscious and unconscious dominate such that automatic responses precede deliberate, reasoned reflection.<sup>[23]</sup> This implicit (unconscious) bias is far more prevalent than explicit bias, and unconscious biases often conflict with one's conscious beliefs and attitudes. For example, in a study of white Americans, Baron and Banaji<sup>[24]</sup> found that both implicit and explicit anti-black bias were cemented by age 6; however, explicit biases gradually diminished toward adulthood, while implicit biases remained stable across development. In this paper, we explore via five illustrative factors how, despite unprejudiced conscious values, unconscious bias can cause engineering educators to contribute to an uneven playing field that influences who gets messages to enter chemical engineering, as well as who succeeds in chemical engineering and who does not. While the literature on implicit bias in chemical engineering is scant, we draw on literature related to STEM more broadly and we use chemical engineering examples where possible.

**Factor #1:** Everyone has implicit biases—unconscious attitudes and stereotypes that develop as a result of automatic processing of information, and affect our understanding and behaviors. The Kirwan Institute motivates the issue by stating, “Research from the neuro-, social, and cognitive sciences show that hidden biases are distressingly pervasive, that they operate largely under the scope of human consciousness, and that they influence the ways in which we see and treat others, even when we are determined to be fair and objective.” Further, our brains are hardwired with probability<sup>[25]</sup> and efficiently classify and stereotype from limited data in prior experiences to infer probability in future experiences.<sup>[24,26,27]</sup> Bordalo, et al.<sup>[28]</sup> present a model of stereotype formation based on a decision maker's tendency to assess a target group by overweighting its representative types in unconscious probability judgments. In this model, stereotypes amplify systematic differences between groups, and the assessment of the target group depends on the reference group to which it is compared. As an example, consider a typical 50-person undergraduate chemical engineering class; based upon ASEE demographic enrollment data,<sup>[29]</sup> a professor would have contact with two African-American, four Hispanic, six Asian, and 38 white students. Using a standard “bell curve” distribution, if seven white students and one black student do more than one standard deviation below average, the comparative distribution of grades is subconsciously processed resulting in a prediction that black students are more likely to be poor performers even if there were more poor-performing white students. Further, our brains tend to remember negative conditions and negative emotions much more vividly than neutral or positive ones.<sup>[30]</sup> Thus, in this example, poor performance stands out far more for minority students than it does for majority students, and the implicit association between poor performance and minority status is established

in a professor's unconscious even though it may conflict with conscious values.

We assert that this probability-driven implicit association is a plausible explanation why—during discussions on efforts to increase diversity in a program—someone brings up the point that “we don't want to reduce the quality of our students.” This association is also prevalent in the literature. Scholarly articles placing diversity in an either/or frame with quality are predominantly centered on the affirmative action debate.<sup>[31-33]</sup> However, numerous articles document that increasing diversity improved quality, breadth, and rigor of STEM content.<sup>[34,35]</sup> It is important to consider the value of diversity, creativity, and broadening perspectives, alongside traditional quantitative metrics, when evaluating students for admissions and scholarships.

**Factor #2:** The domino effect from our brains' (and our students' brains') cataloging probabilities also includes stereotype threat. For example, a student's awareness of these probability perceptions negatively impacts her or his performance because while 100% of their brain energy should be focused on a test, it isn't because 10% (or more) is engaged in an internal battle to not reinforce the stereotype.<sup>[36]</sup> The seminal work by Steele and Aronson<sup>[37]</sup> demonstrated a powerful and deleterious effect of stereotype threat on intellectual performance of African-American males, and on women performing challenging math tests,<sup>[38]</sup> when the subjects had to indicate race and/or gender on the test. Further, they showed that the differences were eliminated when stereotype threat was reduced (*i.e.*, they weren't asked race/gender).

It is valuable to note that positive stereotypes have both beneficial and adverse implications and serve to perpetuate systemic differences in power and privilege.<sup>[39]</sup> In an interesting personal reflection, an Asian-American student explains how he benefitted from technical privilege that resulted from historic probabilities that Asian-Americans are excellent students.<sup>[40]</sup>

**Factor #3:** Unconscious bias and assumptions create a student-to-student and professor-to-student social organization within a class that aligns with expectations of performance and academic achievement. Research has shown that professors and educators allocate their time and resources to those they perceive to have a higher probability of success.<sup>[41]</sup> Thus, an instructors' expectations impact anticipated academic potential and result in differential treatment, becoming a self-fulfilling prophecy of success or failure.<sup>[42]</sup> Combined with stereotype development as described in Factor #2, the effect of implicit bias on expectations for success and resource allocation is likely to disadvantage underserved, underrepresented, and minority students in our programs.

**Factor #4:** Grading and the subsequent calculation of grades should be as objective and stoic as is possible. Several studies have demonstrated differences in test scores that

are graded blindly vs. non-anonymous grading<sup>[43]</sup> even in technical subjects, which are perceived to be very objective. Extensive meta-analysis from studies examining 1,286,350 people revealed no gender differences in math ability, but significant differences in perceptions by parents, teachers, and students of all ages in math ability.<sup>[44]</sup> Perceptions are then reflected in the feedback students receive. As described by Terrier,<sup>[45]</sup> there is substantial evidence that teachers' biases generate self-fulfilling prophecies,<sup>[42,43,46]</sup> produce stereotype threats,<sup>[37,38]</sup> affect students' interest in a subject,<sup>[47,48]</sup> and affect students' levels of effort.<sup>[49]</sup>

**Factor #5:** Students grow, change, and adapt—and should evolve into better and more mature problem solvers. If we function as gatekeepers and withdraw support or resources when a student is faltering, that means we deny the foundations of practice for problem solving and thus the development of resilience, which inherently requires a process of learning and adapting from failures. Daryl Chubin, director of The Center for Advancing Science and Engineering Capacity at AAAS, described a weed-out mentality that is deeply entrenched in STEM culture: “not everybody is good enough to cut it, and we’re going to make it hard for them, and the cream will rise to the top.”<sup>[50]</sup> Professors in this mindset serve as gatekeepers to the profession. Despite the efforts to increase retention in engineering in recent decades, the retention of engineering undergraduate students still hovers around 50% nationally, and the rate of attrition for women and minorities in engineering is disproportionately high.<sup>[51,52]</sup> (The results reported by Lord, et al.<sup>[53]</sup> for six-year graduation rates show lower rates for white women than white men, but higher rates for black women and Hispanic women than their male counterparts. Black and Hispanic male and female students had lower six-year graduation rates than their white counterparts. The data were obtained primarily from large institutions in the southeastern United States, where demographics are different from the rest of the country, so the results might not be representative of other regions and types of schools. Additional discipline-specific data representing institutions nationally is needed for further insight into persistence and retention of students by discipline and by race and gender.) Nevertheless, underrepresented students report less inclusion and comfort in their fields, which reflects forward into retention. While some students leave for “healthy” reasons such as being genuinely drawn to another discipline, many students leave for other reasons such as poor teaching, lack of fit, loss of affinity to a field, changes in self-efficacy, or chilly climate.<sup>[14,15,51,52]</sup> Jones and Okun<sup>[54]</sup> explain that dominant majority culture is perpetuated within organizations, diminishing multiculturalism by effectively requiring its members to conform to the existing culture or standards in order to thrive. Characteristics of white culture include perfectionism, sense of urgency, defensiveness, quantity over quality, emphasis on the written word, paternalism, either/or thinking, power hoarding, fear of open conflict, individualism, progress is bigger/more, and

objectivity.<sup>[54]</sup> These characteristics align closely with weed-out mentality frameworks; those students who readily display these characteristics fit well in engineering and those who do not are treated as if they cannot “hack” it. Given the breadth and quantity of talent needed in our society, professors who transition from a gatekeeping mentality to a coaching and assessing mentality position their programs to graduate more creative, diverse, and adaptable students.

## STRATEGIES FOR PROFESSORS TO MOVE TOWARD INCLUSION

**Factor #1:** What can we do as professors to slow or eliminate our unconscious conflating limited experiences upon future underrepresented students in our classes? The first step is being open to acknowledging that implicit bias is an ongoing influence in our lives<sup>[27]</sup> and that regular, conscious effort on our part is necessary to move public and private attitudes and behaviors toward equal treatment. Second, proactively acknowledging and guiding others through the unfair association between diversity and reduced quality can enable group discussions to move beyond this barrier to engaging in open and transparent discussions that move groups from monocultural to multicultural learning climates.<sup>[55]</sup>

**Factor #2:** Professors who are cognizant of stereotype threat and the negative impacts it can have on our students' learning and mental state can use that knowledge to promote inclusive learning environments. Engineering educators may employ several empirically validated strategies to combat stereotype threat as summarized by Reference 56: (1) emphasize that diversity is valued explicitly and consistently communicate a multicultural ideology; (2) ensure that tests are gender- and race-fair (*e.g.*, by using neutral language free from stereotypes, by collecting demographic information at the end of the test and only when necessary); (3) use tests to facilitate learning, and communicate this to students; (4) convey high standards and actively communicate confidence in students' ability to meet those expectations; and (5) expose students to positive role models from diverse groups through in-class examples and invited speakers. Paying attention to team composition and team dynamics for collaborative group work can better ensure that underrepresented students are not isolated or marginalized. Exercises that draw attention to self-volunteered individual strengths and unique perspectives can increase appreciation for differences and perspectives. It may also be valuable to recognize that well-meaning individuals may pay too much public attention to students they perceive to be weaker, which simultaneously clues the rest of the class into perceived at-risk students and makes the student hyper-aware of stereotype threat. For a more thorough summary of empirically validated strategies to combat stereotype threat, readers are referred to Reference 56. A balance between public and private interactions with students enables the greatest customizations for each student's unique learning needs.

**Factor #3:** What can we do as professors to support student success in such a manner that biased expectations of performance and academic achievement do not influence performance? We can focus on sending consistent messages of high expectations and anticipated success to all students in the class.<sup>[57]</sup> While there is little research to support the elimination or reduction of unconscious bias, its effects can be mitigated through conscious efforts. We can devote our effort to providing access to information, facilitating learning, valuing students' prior experiences and knowledge, and encouraging students to rise to the challenge of learning new material and practicing problem solving. It is valuable to note that equitable strategies allocate time and resources according to need to succeed, for example to compensate for structural barriers that disproportionately disadvantage some groups of students. We can consciously strive to be equitable in our allocation of time and resources to students.

**Factor #4:** One way to mitigate unintended bias is to educate yourself on biases, and work to prevent opportunities for unconscious bias to operate.<sup>[27]</sup> When assessing student learning, this can be done by developing a mechanism for blind grading with the use of rubrics with good inter-rater reliability to measure achievement.<sup>[58]</sup> A robust rubric allows for alternative solution strategies, and good inter-rater reliability ensures consistency among ratings provided by multiple evaluators.

**Factor #5:** To what extent does an instructor's gatekeeper mentality contribute to poor retention in engineering? Combined with invisible barriers such as unconscious bias, we may very well be losing potential talent because of our inability to recognize it and our unwillingness to adapt our culture to accept other approaches to solve engineering challenges. We may also be overlooking raw talents. In a recent study of first- and second-year chemical engineering students, Svihla, et al.<sup>[59]</sup> found that students who lack pre-college engineering knowledge and have low confidence and ability to succeed in engineering, demonstrated more expert problem-framing ability. These characteristics of perceived lack of engineering knowledge and low confidence are common for students from underrepresented groups in engineering. Thus, limited prior experience and low confidence in engineering should not be viewed as deficits, rather as indicators of assets that may help students develop into design engineers.

In summary, each of us are products of past interactions experienced either directly or via stories. Due to sheer numbers, our profession and each of us within it have more limited interactions with students, colleagues, and professionals from underrepresented and underserved groups. Due to these lower numbers and greater retention of negative events, we are predisposed to think that students from underrepresented and underserved groups will be poorer students. Further, data show we are less likely to offer support and resources to those we expect, based on our unconscious bias, to be poorer students. Because students are also predisposed toward the

same biases, underrepresented students are less likely to be sought after for group assignments, they often tend to be socially excluded and isolated from study groups,<sup>[60,61]</sup> and they internally battle things like stereotype threat issues. Studies that explore why students leave engineering have revealed that women and minorities predominantly leave because of issues related to self-efficacy and sense of belonging more than any ability metric.<sup>[14,62]</sup>

Thus, readers are encouraged to revisit weed-out strategies within their own programs. While these are perceived to select based on skills and abilities, indicators suggest they select based on conformance to characteristics of a dominant majority culture. Transformation of assessment tools to measure creativity, problem-solving, breadth, quality, and rigor would advantage all students in a program.

In order to attract and retain the best talent in science and engineering professions, the National Academies call for elimination of all forms of bias that may hinder academic career success in science and engineering.<sup>[63]</sup> Understanding and mitigating unconscious bias—our own unconscious biases—is crucial to creating a fair, inclusive, and diverse learning environment. To begin this journey, the Harvard Implicit Association Test (<<https://implicit.harvard.edu/implicit/takeatest.html>>) can be an eye-opening starting point that might reveal implicit attitudes of which you were not consciously aware. Your institution may provide training to address unconscious bias, and if not, there are online resources available. One excellent collection is Google's un biasing resources, which are particularly accessible for beginners.<sup>[27]</sup>

To mitigate bias and support the academic success of all students, we can (1) eliminate opportunities for unconscious bias to operate, *e.g.*, through blind grading and management of groups; (2) send strong and consistent messages of high expectations and anticipation of academic achievement; and (3) consciously strive for equitable allocation of time and resources to all students.

In closing, ignoring historical indicators of exclusion and continuing traditions of conformance to an inflexible engineering culture will hinder our profession and its ability to adapt for a sustainable, inclusive future. As professors, we each have a deep fascination and love of learning. We can learn from our students and our colleagues, an increasing number of whom hail from backgrounds different from our own.<sup>[64]</sup> Everyone has experiences, approaches, and perspectives that enrich and complement engineering solutions to societal challenges. This grand challenge, of leveraging and facilitating growth and success in all of our students, is a challenge worth undertaking to remain competitive in a global economy. In our roles as transmitters of knowledge, facilitators of learning, and assessors of creativity and quality—but hopefully not as gatekeepers or trainers to conformity—we shape the future of the chemical engineering profession. Many educators hold fairness and egalitarianism as core

values that we strive to uphold in our professional work and personal lives, so proactively working to evaluate and support students based strictly on student potential and performance is impactful. Improving diversity in a workforce has positive effects on innovation, productivity, and financial performance, and improving inclusion has positive effects on retention and performance.

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## REFERENCES

- National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads*. Washington, D.C.: The National Academies Press, 2011
- C. Herring, "Does Diversity Pay?: Race, Gender, and the Business Case for Diversity," *American Sociological Review*, **74**, 208 (2009)
- Carter, N.M., and H.M. Wagner, "Women Board Directors: A comparison of economic results," The bottom line: corporate performance and women's representation on boards (2004-2008), 2011 Available: <[http://www.catalyst.org/system/files/the\\_bottom\\_line\\_corporate\\_performance\\_and\\_women%27s\\_representation\\_on\\_boards\\_%282004-2008%29.pdf](http://www.catalyst.org/system/files/the_bottom_line_corporate_performance_and_women%27s_representation_on_boards_%282004-2008%29.pdf)> [Accessed: Jul. 31, 2017]
- Devillard, S., W. Graven, E. Lawson, R. Paradise, and S. Sancier-Sultan, "Making the Breakthrough," *Women Matter*, 2012
- Fayer, S., A. Lacey, and A. Watson, "STEM Occupations: Past, Present, and Future," *Spotlight on Statistics*, U.S. Bureau of Labor Statistics, (2017)
- Reason, R.D., B.E. Cox, B.R.L. Quayle, and P.T. Terenzini, "Faculty and Institutional Factors That Promote Student Encounters With Difference in First-Year Courses," *Review of Higher Education*, **33**, 391 (2010)
- Smith, H., R. Parr, R. Woods, B. Bauer, and T. Abraham, "Five Years After Graduation: Undergraduate Cross-Group Friendships and Multicultural Curriculum Predict Current Attitudes and Activities," *J. College Student Development*, **51**, 385 (2010)
- Gurin, P., "Expert Report. 'Gratz et al. v. Bollinger, et al.' No. 97-75321 (E.D. Mich.); 'Grutter, et al. v. Bollinger, et al.' No. 97-75928 (E.D. Mich.)," *Equity & Excellence in Education*, **32**, 36, 09/01/1999
- Pascarella, E.T., and P.T. Terenzini, *How College Affects Students: A Third Decade of Research*, vol. 2. San Francisco: Jossey Bass (2005)
- Pascarella, E.T., and P.T. Terenzini, *How College Affects Students: Findings and Insights From Twenty Years of Research*, vol. 2. San Francisco: Jossey Bass (1991)
- Milem, J., "The Educational Benefits of Diversity: Evidence From Multiple Sectors," in *Compelling Interest: Examining The Evidence On Racial Dynamics In Higher Education*, M. Chang, D. Witt, J. Jones, and K. Hakuta, Eds., Stanford, CA: Stanford University Press, 2003, pp. 126-169
- Reason, R.D., P.T. Terenzini, and R.J. Domingo, "Developing Academic Competence in the First Year Of College," *Research in Higher Education*, **47**, 149 (2006)
- Umbach, P.D., and G.D. Kuh, "Students' Experiences With Diversity at Liberal Arts Colleges: Another Claim For Distinctiveness," *J. Higher Education*, **77**, 169 (2006)
- Dennehy, T.C., and N. Dasgupta, "Female Peer Mentors Early in College Increase Women's Positive Academic Experiences and Retention in Engineering," *Proceedings of the National Academy of Sciences of the United States of America*, **114**, 5964 Jun 2017
- National Academy of Sciences, National Academy of Engineering, and National Academy of Medicine, *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways*, Washington, D.C.: The National Academies Press, 2016, pp. 59-74
- American Institute of Chemical Engineers, *Mission Statement*. Available: <<https://www.aiche.org/about/mission-vision>> [Accessed: Dec. 1, 2017]
- American Institute of Chemical Engineers, (2015) *Code of Ethics*. Available: <<https://www.aiche.org/about/code-ethics>> [Accessed: Dec. 1, 2017]
- Haring-Smith, T., "Broadening Our Definition of Diversity," *Liberal Education*, **98**(2) (2012). Available: <<https://www.aacu.org/publications-research/periodicals/broadening-our-definition-diversity>> [Accessed: Nov. 1, 2017]
- AAC&U, *Making Excellence Inclusive*, Available: <<https://www.aacu.org/making-excellence-inclusive>>, [Accessed: Nov. 1, 2017]
- Ferdman, B.M., "The Practice of Inclusion in Diverse Organizations: Toward a Systemic and Inclusive Framework," in *Diversity at Work: The Practice of Inclusion*, Somerset, NJ: Wiley and Sons, Inc., 2013, p. 52
- Bendick Jr., M., "Measure Inclusion, Not Diversity," presented at the SHRM Diversity Conference and Exposition, Atlanta, GA, 2008
- Engage to excel: Producing One Million Additional College Graduates With Degrees in Science, Technology, Engineering and Mathematics*, ed. Washington, DC: Executive Office of the President, President's Council of Advisors on Science and Technology, 2012
- Bargh, J.A., and E. Morsella, "The Unconscious Mind," *Perspectives on Psychological Science: A Journal of the Association for Psychological Science*, **3**, 73 (2008)
- Baron, A.S., and M.R. Banaji, "The Development of Implicit Attitudes: Evidence of Race Evaluations From Ages 6 and 10 and Adulthood," *Psychological Science*, **17**, 53 (2006)
- Waismeyer, A., A.N. Meltzoff, and A. Gopnik, "Causal Learning From Probabilistic Events in 24-Month-Olds: An Action Measure," *Developmental Science*, **18**, 175, Jan 2015
- Bock, L., and B. Welle, *You Don't Know What You Don't Know: How Our Unconscious Minds Undermine The Workplace*, (2014) Available: <<https://googleblog.blogspot.com/2014/09/you-dont-know-what-you-dont-know-how.html>> [Accessed: Jul. 31, 2017]
- Google. (2017). *ReWork: Unbiasing*. Available: <<https://rework.withgoogle.com/subjects/unbiasing/>> [Accessed: Jul. 31, 2017]
- Bordalo, P., K. Coffman, N. Gennaioli, and A. Shleifer, "Stereotypes," *The Quarterly Journal of Economics*, 1753 (2016)
- Yoder, B., *ASEE Profiles of Engineering and Engineering Technology Colleges Data Mining Tool*, ASEE, Washington, D.C. (2016)
- Xie, W.Z., and W.W. Zhang, "Negative Emotion Enhances Mnemonic Precision and Subjective Feelings of Remembering in Visual Long-Term Memory," *Cognition*, **166**, 73, Sep 2017
- Chan, J., and E. Eyster, "Does Banning Affirmative Action Lower College Student Quality?," *The American Economic Review*, **93**, 858 (2003)
- Antonovics, K., and B. Backes, "The Effect of Banning Affirmative Action on College Admissions Policies and Student Quality," *J. Human Resources*, **49**, 295, Spr 2014
- Arcidiacono, P., and M. Lovenheim, "Affirmative Action and the Quality-Fit Trade-off," *J. Economic Literature*, **54**, 3, Mar 2016
- Roksa, J., C.A. Kilgo, T.L. Trolan, E.T. Pascarella, C. Blaich, and K.S. Wise, "Engaging with Diversity: How Positive and Negative Diversity Interactions Influence Students' Cognitive Outcomes," *J. Higher Education*, **88**, 297 (2017)
- Thiry, H., T. Archie, M. Arreola-Pena, and S. Laursen, "Linkages Between Youth Diversity and Organizational and Program Characteristics of Out-Of-School-Time Science Programs: A Mixed-Methods Study," *International J. Science Education Part B-Communication and Public Engagement*, **7**, 121, Jun 2017
- Steele, C.M., S.J. Spencer, and J. Aronson, "Contending With Group Image: The Psychology of Stereotype and Social Identity Threat,"

- Advances in Experimental Social Psychology*, **34**, 379 (2002)
37. Steele, C.M., and J. Aronson, "Stereotype Threat and the Intellectual Test Performance of African Americans," *J. Personality and Social Psychology*, **69**(5), 797 (1995)
  38. Spencer, S.J., C.M. Steele, and D.M. Quinn, "Stereotype Threat and Women's Math Performance," *J. Experimental Social Psychology*, **35**, 4 (1999)
  39. Czopp, A.M., A.C. Kay, and S. Cheryan, "Positive Stereotypes Are Pervasive and Powerful," *Perspectives on Psychological Science*, **10**, 451 (2015)
  40. Guo, P., "Silent Technical Privilege," *Slate* (2014) Available: <[http://www.slate.com/articles/technology/technology/2014/01/programmer\\_privilege\\_as\\_an\\_asian\\_male\\_computer\\_science\\_major\\_everyone\\_gave.html](http://www.slate.com/articles/technology/technology/2014/01/programmer_privilege_as_an_asian_male_computer_science_major_everyone_gave.html)> [Accessed: Jul. 22, 2017]
  41. Moss-Racusin, C.A., J.F. Dovidio, V.L. Brescoll, M.J. Graham, and J. Handelsman, "Science Faculty's Subtle Gender Biases Favor Male Students," *Proceedings of the National Academy of Sciences of the United States of America*, **109**, 16474, 09/17 2012
  42. Jussim, L., and J. Eccles, "Teachers' Expectations II: Construction and Reflection of Student Achievement," *J. Personality and Social Psychology*, **63**, 947 (1992)
  43. Lavy, V., and E. Sand, "On the Origins of Gender Human Capital Gaps: Short and Long Term Consequences of Teachers' Stereotypical Biases," *National Bureau of Economic Research Working Paper Series*, No. 20909, Cambridge, MA (2015)
  44. Lindberg, S.M., J.S. Hyde, J.L. Petersen, and M.C. Linn, "New Trends in Gender and Mathematics Performance: A Meta-Analysis," *Psychological Bulletin*, **136**, 1123 (2010)
  45. Terrier, C., "Boys Lag Behind: How Teachers' Gender Biases Affect Student Achievement," *School Effectiveness and Inequality Initiative*, Working Paper #2016.07, Cambridge, MA (2016)
  46. Riegle-Crumb, C., and M. Humphries, "Exploring Bias in Math Teachers' Perceptions of Students' Ability by Gender and Race/Ethnicity," *Gender & Society*, **26**, 290, Apr 2012
  47. Marsh, H.W., and R.G. Craven, "Academic Self-Concept: Beyond the Dust-Bowl," in *Handbook of Classroom Assessment*, G.D. Phye, Ed., San Diego, CA: Academic Press, (1997), pp. 131-198
  48. Trautwein, U., O. Ludtke, H.W. Marsh, O. Koller, and J. Baumert, "Tracking, Grading, and Student Motivation: Using Group Composition and Status to Pre-Dict Self-Concept and Interest in Ninth-Grade Mathematics," *J. Educational Psychology*, **4**, 788 (2006)
  49. Mechtenberg, L., "Cheap Talk In The Classroom: How Biased Grading at School Explains Gender Differences in Achievements, Career Choices and Wages," *Review of Economic Studies*, **76**, 1431 (2009)
  50. Epstein, D., *So That's Why They're Leaving*, (2006) Available: <<https://www.insidehighered.com/news/2006/07/26/scipipeline>> [Accessed: Jan. 1, 2018]
  51. Geisinger, B.N., and R.D. Raman, "Why They Leave: Understanding Student Attrition From Engineering Majors," *Agricultural and Biosystems Engineering*, **29**, 914 (2013)
  52. Chen, X., and W. Thomas, *Students Who Study Science, Technology, Engineering, and Mathematics (STEM) in Postsecondary Education*, NCES 2009-161, U.S. Department of Education, Washington, D.C. July, 2009
  53. Lord, S.M., R.A. Layton, M.O. Ohland, C.E. Brawner, and R.A. Long, "A Multi-Institution Study Of Student Demographics And Outcomes In Chemical Engineering," *Chem. Eng. Ed.*, **48**, 231 (2014)
  54. Jones, K., and T. Okun, *White Supremacy Culture*, Portland, OR: Western States Center: ChangeWork (2001)
  55. Jackson, B.W., "Theory and Practice of Multicultural Organization Development," in *The NTL Handbook of Organization Development and Change*: Wiley, San Francisco, pp. 175-192 (2014)
  56. *Empirically Validated Strategies to Reduce Stereotype Threat* (2017). Available: <<https://ed.stanford.edu/sites/default/files/intervention-shandout.pdf>> [Accessed: Dec. 6, 2017]
  57. Rist, C., "Student Social Class and Teacher Expectations: The Self-Fulfilling Prophecy in Ghetto Education," in *Challenging the Myth: the Schools, the Blacks, and the Poor*, Cambridge, MA: Harvard Educational Review (1971)
  58. Dawson, P., "Assessment Rubrics: Towards Clearer and More Replicable Design, Research and Practice," *Assessment & Evaluation in Higher Education*, **42**, 347 (2017)
  59. Svihla, V., A.K. Datye, J.R. Gomez, V. Law, and S. Bowers, "Mapping Assets of Diverse Groups for Chemical Engineering Design Problem Framing Ability," in *ASEE Annual Conference* New Orleans, LA (2016)
  60. Ackerman, P.L., R. Kanfer, and M.E. Beier, "Trait Complex, Cognitive Ability, and Domain Knowledge Predictors of Baccalaureate Success, STEM Persistence, and Gender Differences," *J. Educational Psychology*, **105**, 911, Aug 2013
  61. Cheryan, S., A. Master, and A.N. Meltzoff, "Cultural Stereotypes as Gatekeepers: Increasing Girls' Interest in Computer Science and Engineering by Diversifying Stereotypes," *Frontiers in Psychology*, **6**, 1 (Feb 2015)
  62. Charleston, L., and R. Leon, "Constructing Self-Efficacy in STEM Graduate Education," *J. for Multicultural Education*, **10**, 152 (2016)
  63. National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*, National Academies Press, Washington, D.C. (2006)
  64. National Science Foundation, National Center for Science and Engineering Statistics (NCSES), *Science and Engineering Indicators 2014*, Arlington, VA, NSB 14-01 (2014) □