Using Data to Mitigate Bias in Engineering Faculty Career Outcomes

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Background

Multiple milestones mark faculty career progress with advancement determined by institutional performance evaluation processes that are vulnerable to implicit and explicit biases in hiring, tenure and promotion decisions, merit evaluations, compensation, and leadership appointments. Even small differences in performance reviews and compensation can accumulate quickly. If left unaddressed, the resulting inequities inhibit the academic success of the faculty at large, as well as produce time-consuming grievances or costly early departures of faculty. Monitoring career outcomes by regular collection of relevant data on compensation and evaluation, openness to challenging and changing institutional policies and practices that foster unequal outcomes, and accountability of academic leadership for producing an equitable and inclusive faculty culture can help institutions avoid costly reactive adjustments to remedy entrenched inequities. We assert that a sustained program of data collection and analysis can identify biases that limit faculty career success as well as the institutional behaviors that enable unequal outcomes. Ultimately robust data analysis and communication will be the basis for new structures to sustain a productive and diverse faculty.

Inclusion has been broadly defined as: "active, intentional and ongoing engagement in diversity—in the curriculum, in the co-curriculum, and in communities (intellectual, social, cultural, geographical) with which individuals might connect—in ways that increase awareness, content knowledge, cognitive sophistication and empathic understanding of the complex ways individuals interact within systems and institutions" [1, para. 6].

For academic institutions the goal of inclusion addresses recognition of individuals across multiple identity factors (e.g., race, ethnicity, gender identity, and culture), i.e., "intersectionality." [2] Among all faculty in higher education institutions across all disciplines, the representation of women in full time positions remains far from parity with the general US population. Even less represented are African-American, Latinx, Asian-American, and Native American women who comprise just over 20% of full-time women faculty [3]. Though the percent of women and underrepresented minorities on all faculties has increased since 1993 [3], the diversity of faculty in tenured and tenure track (T/TT) positions declined by almost one-third between 1993 and 2013, from 35.6% to 24.2% [4]. Fox contends institutional patterns of hiring, resource allocation, and career development must change if an inclusive culture is to be achieved [5, p. 98].

Equity between majority and minority workers as measured by equal pay has been positively associated with workplace inclusion and diversity. Quesenberry and Trauth found that equal pay and perceived equal treatment, especially opportunities to advance to management, were associated with two important "career anchors:" organizational security and managerial

competence, and with persistence of women in the information technology workforce [6]. We contend that systemic changes in academic institutional behavior can be expected to produce more equitable outcomes for women faculty in engineering and computer science, where salary, performance evaluation, tenure, and promotion decisions are strongly embedded in the academic organization. For example, the gender pay gap for faculty persists at between 4% and 6% across all ranks and disciplines [7]. Barriers to faculty salary equity include diminishing representation at the higher-paid tenured ranks due to lower rates of promotion, especially at doctoral-degree granting institutions, as well as lower starting salaries [7], [8]. Because faculty salaries are influenced by multiple factors including seniority, rank, prior experience, market conditions, educational pedigree, publications, research funding, valuation of research quality, service and leadership assignments, and teaching evaluations, identifying the effect of bias in any of these factors cannot be done using simple salary comparisons [9].

A number of factors may account for differences in faculty career progress. For example, traditional factors used to measure scholarly contributions, such as quantity of publications, citations, or external funding may be sources of bias toward minoritized populations. Some researchers have found that men have a higher number of publications than women when hired, possibly due to e.g., better mentoring or greater access to post-doctoral fellowships, and this initial gap may be difficult to close before tenure review [9]. In addition, the perceived proximity to promotion to full professor can motivate an increase in the number of research publications; conversely, the study suggests that longer time spent in a rank decreases the publication quantity and leads to further delays in promotion [10]. This suggests a gain in productivity by supporting more timely promotion to full professor, especially for women who may have languished at the associate professor rank. At the assistant professor rank, young children may influence both research and teaching activity. Fox found that productivity did vary for newer faculty. Although, interestingly, women assistant professors with pre-school children were the most productive in their cohort [11], thus belying gender stereotypes related to family responsibilities. Finally, some academic departments place less value on teaching, advising, and service versus research tasks such as writing, editing, and presentations [12] that can result in bias in promotion decisions.

While stated guidelines to attaining tenure in engineering may seem clear, criteria for advancement from associate to full professor tend to be more variable and subjective [13]. Factors such as "high impact" and "international renown" are especially subject to interpretation or linked to recognition factors such as external letters, awards, and invitations to give talks, which are themselves inherently biased. New assistant professors who often have mentors providing guidance on preparing for tenure often receive no mentoring as associate professors, compounding the bias of vague guidelines for promotion to full professor.

Letters from external references often play a critical role in tenure and promotion decisions. Review committees incorporate reference attributes such as prestige of their institution and other recognition markers that favor traditional majority models of success, to the exclusion of women and faculty of color. Research has shown that significant gender bias may exist in external letters for women candidates for academic positions [14], [15], [16].

Salary equity issues can arise from hidden biases in the evaluation process. Even small salary differences awarded at the assistant professor level can magnify over time. In contrast, all faculty receiving the same percentage award in a specific rank can minimize perceptions of gender biases [9]. Salaries skewed by off-cycle retention offers, primarily from outside job offers used to initiate counteroffers from the home institution, can disrupt any good intentions around maintaining or achieving equity in the merit review and salary awards processes. Our data analysis reveals that men receive an average pay increase justified by retention that is more than $4,000 greater than the average award to women. In addition, such offers, which are not performance based, can include incentives such as consideration for promotion, support for students and equipment, which further widens the pay gap in the future.

Previous studies of the role of equity in career progress and compensation to achieve diverse and inclusive faculty cultures guides this work effort. In 2018, we inaugurated a program of data collection aimed at identifying the institutional structures and practices associated with underrepresentation of women on the faculty in the fields of engineering and computer science at the University of Colorado Boulder College of Engineering and Applied Science.

Case Study of a Data-Based Approach

The University of Colorado Boulder (UCB) is a comprehensive, doctoral degree granting institution denoted as very high research activity [17]. The university enrolls over 37,000 students and employees nearly 1,300 tenured/tenure-track faculty across all divisions, schools, and colleges. The College of Engineering and Applied Science (CEAS) has been proactive in supporting student diversity for more than 40 years [18] but has fewer coordinated efforts to recruit and retain diverse faculty. Moreover, there have been no credible measures of the success of these efforts, much less their long-term sustainability as measured by institutional change.

We began with a primary indicator: engineering faculty demographics. As of fall of 2019, the CEAS had 348 tenured/tenure track (T/TT) and instructional faculty. Of the T/TT faculty, 23% were women. The shortage of women at the professor level is greater, with women making up only 18% of full professors within the college. In Table I are the percentages of T/TT women faculty at the various ranks in the CEAS.

Table I. 2019 women's T/TT representations by rank.

Faculty Title	% Women
Assistant Professor	25.6%
Associate Professor	30.4%
Full Professor	18.3%
% of All T/TT Faculty	*23.4%*

The low numbers of women at the senior ranks means the pool of experienced women available for appointments as department chairs, and other leadership positions that require the rank of full professor is limited. The College hired the first women faculty in 1982, but it was not until the fall of 2008 that the College had its first female department chair. During

the ensuing decade, only one woman held a chair position at any time. By fall 2019, women held no department chair positions and only one program director position in the six departments and eight degree-granting programs. Yet women hold two of the three faculty Associate Dean positions in the College (for undergraduate education and faculty advancement), indicating that the CEAS has the capacity to promote more women faculty to leadership positions [19]. One of these associate deanships is held by a non-tenure-track faculty member, which has not happened in more than 20 years.

While demographic data indicate discrepancies in faculty career progression, further analysis can reveal more meaningful and actionable information. In our next step, we hypothesized explanations for the demographic data and collected secondary data to both test the hypotheses and to identify institutional policies and practices associated with possible causes of bias. Primary demographic data in our institution lists the numbers of faculty by name, department/program, gender, ethnicity, degree date, current rank, appointment date, tenure and promotion dates, current salaries, annual increases, and merit evaluations. Secondary data include gender differences in career progression, long-term trends in annual raises, performance reviews, and service assignments. Comparing cohorts based on their appointment date or years since degree enables us to highlight when and how gender differences occur. See Table II for examples of these types of data analyses conducted in the CEAS.

Table II. Examples of CEAS faculty data analyses.

Primary data	*Secondary data*	*Structural biases identified*	*Ideas for structural change*
Faculty Demographic Data (representation of women in all ranks)	Time to promotion Career progression through cohort tracking	Gender differences in parental leave impact Implicit or biased criteria used in performance evaluation	More flexible tenure clock for all faculty Transparent and inclusive criteria for evaluating research, teaching, and service
Faculty Salaries	Long-term trends in annual raises to men and women	Retention offers primarily benefit majority faculty pay and resources Gender differences in pay at the time of hire.	Elimination of off-cycle salary increases to address actual or anticipated outside offers Leadership accountability for closing pay gaps quickly

Faculty Performance Evaluations	Ratings by cohort or across ranks Gender differences in performance reviews Gender differences in service activities	Narrow, purely quantitative, often gender-biased measures of teaching, research and service. Overreliance on short term (annual) measures of performance	Multiple measures of performance, including qualitative measures Leadership accountability for evaluation adjustments More formalized mentoring

An example of using the analysis of primary data to test explanations using secondary data involves parental leave. We posed the question: Are there different career outcomes from parental leave by gender? Many new faculty have children after being hired, and before tenure. Like an increasing number of universities, the University of Colorado offers parental leave after a child's birth, adoption, or foster-placement, and parents can delay tenure review with a clock stoppage—also known as, "stopping the tenure clock—for one year [20]. The expectation is that taking parental leave will lead to tenure one year later than those not taking parental leave. Both women and men who become parents can opt to take parental leave, and some policies at other institutions do include discussions about being the "primary caregiver" and the degree or type of academic work conducted during parental leave [21]. An explicit assumption is that a parent's primary activity on leave is early child care, with no expectations for research, teaching or service. In the CEAS, the ratio of men:women taking parental leave is 2.5:1, which is proportionate to the faculty demographics. However, we found that many men taking parental did not stop their tenure clock, instead were considered for *early* tenure (rather than the expected one year later), whereas *no* women taking parental leave were put up for early tenure. This finding corresponds to those of Antecol and team [20], who found that in economics men are 17 % more likely and women are 19% less likely to get tenure at the expected time once there is a

gender-neutral clock stopping policy. One inference is that the men used the parental leave for academic productivity such as writing papers and grants, while the women focused on physical recovery and parenting tasks. In this case, a well-intentioned, supposedly gender-neutral policy has led to unequal outcomes and needs further exploration before adjusting policy or practice.

Figure 1. 2019 academic year salaries of tenured/tenure track faculty receiving the highest annual merit rating ("far exceeds expectations"). Dots are individual faculty; lines are linear regressions: open blue circles and long dash trendline for men; solid red circles and short dotted trendline for women.

Another area of concern involves promotion and tenure. It has been reported that a smaller proportion of women assistant professors are awarded tenure compared to
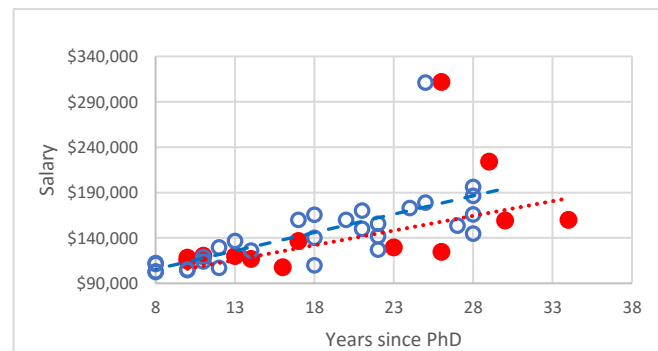
men, and the time between gaining tenure and promotion to full professor is generally longer for women [21]. As shown in Table I, in the CEAS, the fraction of full professors who are women is only 18%, while women are 30% of the associate professors. Some of the difference may reflect an increase in hiring women faculty, although only 25% of the assistant professors are women. However, another explanation for the decline in percentage of women full professors may be due to either lack of support for the advancement of women associate professors or bias in promotion decisions. In fact, we found that the median time to tenure in CEAS is five years for men and six years for women. While some colleges have created informational resources to address this discrepancy, those "solutions" put the burden onto the women associate professors themselves. Examination of the existing system reveals a flawed process that rewards the "squeaky wheel," mostly men who advocate for themselves more vocally compared to women, have informal or formal mentors to guide them, or are perceived to exhibit more drive or motivation [22]. Also, the policies at other institutions and ours demonstrate unspecific language and ambiguity regarding the quantity and quality of work products required for promotion to full professor [23].

A narrow set of performance measures, established over time by mostly majority male administrators and senior faculty, may explain salary differences. At the CEAS, annual performance evaluations are the basis of annual pay raises and even small inequities accumulate over time. Our analysis of salary data for the highest rated CEAS faculty, shown in Figure 1, suggests that many women even with similar performance evaluations and seniority get paid less than their male counterparts. These gaps are exacerbated by increasing use of individually negotiated salary raises justified by actual or anticipated outside offers. In 2017-2018, 34 of these "retention" offers resulted in substantial raises. Eight of these (23.5%) were made to women. These retention offers included responses to bona fide written outside offers, other raises outside the normal merit evaluation called "pre-emptive retention," and a few to achieve salary equity for women faculty. Though these raises occurred in all departments, the women faculty who received offers are housed in only three of the college's six departments. Because these offers often also contain other significant resources (stipends for PhD students and postdocs, lab facilities and equipment, course buy-outs, etc.), they convey additional performance benefits to the recipients. This method of increasing compensation offers numerous opportunities for biased decisions.

Compounding the problem of retaining diverse faculty are voluntary departure rates for women faculty, which are double those for men. Figure 2 (a) and (b) shows the longitudinal career progression and outcomes of the cohort of men and women faculty, respectively, hired as assistant professors at UCB in 2002. While 30% of the men left the institution during the 15-year tracking period, over 50% of women departed. Moreover, a small fraction of women faculty chose to transition to non-tenure track pathways, and only 20% of women gained the rank of full professor in 15 years, compared to 40% of men. In each cohort, a few chose administrative/leadership roles for a portion of their time as associate or full professors. This representation of the leaky pipeline for women confirms the need for actions that will enable women to gain tenure and promotion in more equitable conditions, and for examination of the culture in the departments and campus that will support women's retention.
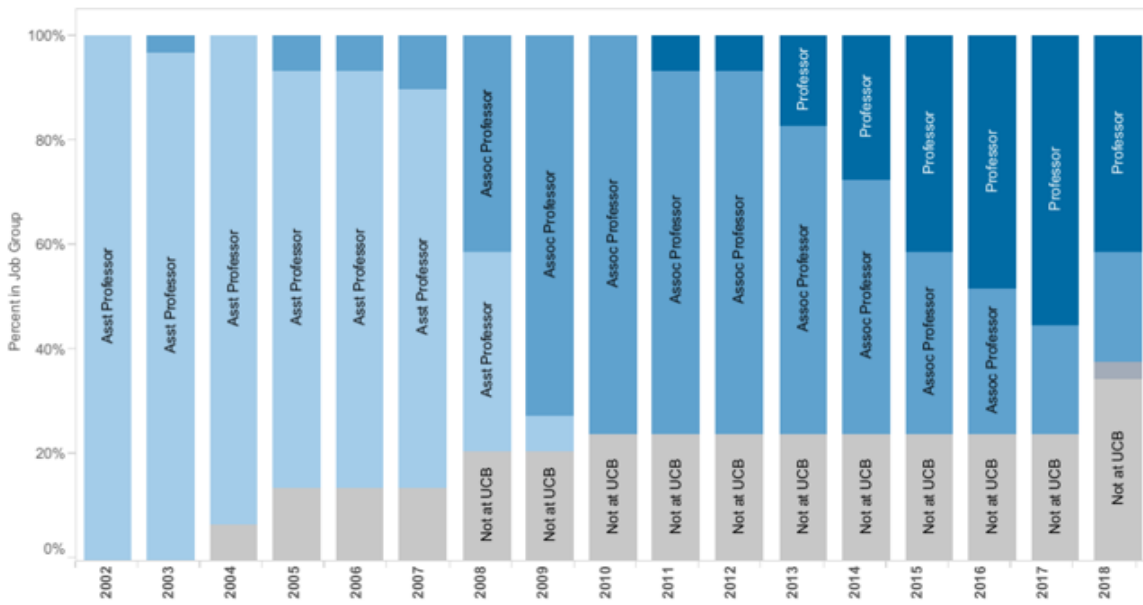
Figure 2 (a). Longitudinal retention for the UCB campus cohort of 29 male assistant professors hired in 2002. See color explanation below in (b).
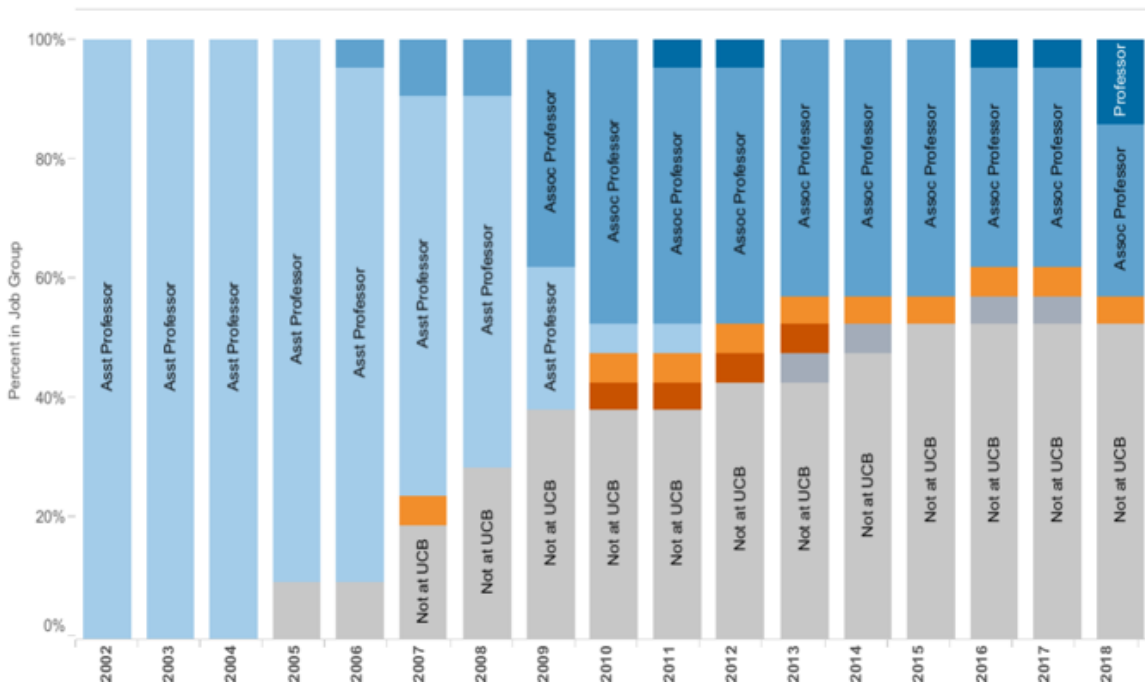

Figure 2 (b). Longitudinal retention for the campus cohort of 21 female assistant professors hired in 2002. Light blue bars represent the % of assistant professors, darker blue shades are tenured associate professors, and darkest blue are full professors. Normal tenure year was 2007. Grey bars represent the % of cohort faculty leaving UCB. Orange/red shades denote instructional faculty, and dark grey bars denote administrative role.

Using Data to Make Institutional Change

Leadership and culture: In 2017, the CEAS created a new position, Associate Dean for Faculty Advancement, whose role is to oversee the processes for faculty recruitment and hiring, annual merit reviews, salary raises and adjustments, and promotion and tenure decisions. An important change was including as part of the position structuring equity and diversity outcomes in these processes, including support for new program personnel within that administrative office, to inform leadership. This is a different strategy than the more common creation of a separate program and staff position focused exclusively on diversity, equity, and inclusion. At the least, embedding diversity and inclusion into the responsibilities of the Associate Dean for Faculty Advancement makes a direct link between findings around inequities, bias, and mitigation through changes to practices around performance evaluation, hiring, promotion, and tenure. For example, the associate dean disseminates annual salary equity data to department chairs and monitors progress to closing pay gaps on an annual basis. With data provided by the campus-level Equal Employment Opportunity Commission (EEOC)/Affirmative Action Officer, the associate dean also reports on the demographics of faculty applicants, candidate screening and hiring outcomes of faculty searches. Incorporating data collection, analysis and dissemination around equity into hiring, compensation and career advancement of *all* faculty prevents the unfortunate effect of isolating and marginalizing diversity and inclusion activities, as has been reported at some institutions [24], [25], [26].

Reporting statistical analysis of salary data linking background information about individual pay gaps has resulted in some corrective actions in the CEAS. At least one department has responded with salary increases to achieve gender pay parity within a specific merit cohort, without the motivation of an outside job offer. The annual merit rating system has been revised to correct what we found to be significant variability in ratings with two or even three significant figures on a five-point scale which suggested rating accuracies well beyond what was possible using current processes and used to justify salary increase differentials among those with statistically identical ratings. Now the scale uses only integer ratings that supports greater equity in performance-based salary increases. While some department and program leaders support reducing inequities, funds for salary raises, especially at public universities, are limited. Meeting a goal of salary equity requires leadership at the college level to provide a unified set of equity objectives, data, and financial resources to close pay gaps that have been accumulating for years. After that, robust monitoring is necessary to reinforce accountability for sustaining equitable pay scales.

The CEAS promotion and tenure review committee suffered from two trends that became sources of bias in reviews. First, many members were very senior (even retired) faculty – primarily white males, supporting narrow quantitative criteria for evaluating scholarship, soliciting and weighing external letters, and even the appropriateness of new research topics such as engineering education. A second was the result of a general tendency of faculty to avoid service on internal committees, which also skewed the committee demographics to faculty who were, in fact, no longer active in research or innovative teaching. In spite of the prescribed three-year term, there was a somewhat bimodal distribution of members' term lengths; some served for

only a year or two, and others for as long as 12 years. Beginning in 2017, the Associate Dean for Faculty Advancement had oversight of the committee membership and its operation, and restored both term lengths and vetted faculty nominated to the committee. Of the 12 committee members, five, including the chair, are now women; in the past, there had never been more than one. Enforcement of staggered three-year term limits insure fresh input while maintaining consistent procedures for review. At times, a disruptive action to reverse an entrenched process that fosters bias is necessary. The promotion and tenure committee is one of the most important committees in the college, and rapid change to improve decision-making can serve as a model for more inclusive review processes at the department and program levels.

In summary, we have developed a process to continuously examine demographic and career progress data to produce timely findings, identify trends, and foster better practices to promote a more inclusive faculty culture in engineering, develop new initiatives, and support accountability of College leadership. The data-based approach led to, and will continue to, promote structural changes to mitigate bias in faculty performance review, salary, and promotion policies. The expected outcomes, which also require monitoring, are a more inclusive faculty culture whose diversity benefits the entire academic enterprise.

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