

Correction

OPINION

Correction for “Opinion: Gender diversity leads to better science,” by Mathias Wullum Nielsen, Sharla Alegria, Love Börjeson, Henry Etzkowitz, Holly J. Falk-Krzesinski, Aparna Joshi, Erin Leahey, Laurel Smith-Doerr, Anita Williams Woolley, and Londa Schiebinger, which appeared in issue 8, February 21, 2017, of *Proc Natl Acad Sci USA* (114:1740–1742; 10.1073/pnas.1700616114).

The editors note that, due to a printer’s error, references 7 and 8 were each inadvertently repeated in the text, in the second and third full paragraphs on page 1741, respectively. The extraneous callouts to references 7 and 8 have now been removed.

www.pnas.org/cgi/doi/10.1073/pnas.1703146114

Gender diversity leads to better science

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Pick up any recent policy paper on women's participation in science and you will find assurances that gender diversity enhances knowledge outcomes. Universities and science-policy stakeholders, including the European Commission and the US National Institutes of Health, readily subscribe to this argument (1–3). But is there, in fact, a gender-diversity dividend in science?

The data suggest that there is. Under the right conditions, teams may benefit from various types of diversity, including scientific discipline, work experience, gender, ethnicity, and nationality. In this paper, we highlight gender diversity (Fig. 1). Guided by key research findings, we propose the following

“mechanisms for innovation” specifying why gender diversity matters for scientific discovery and what managers should do to maximize its benefits (Fig. 2). Encouraging greater diversity is not only the right thing to do: it allows scientific organizations to derive an “innovation dividend” that leads to smarter, more creative teams, hence opening the door to new discoveries.

Productive Team Mechanisms

Well-run, well-performing research teams have become increasingly crucial to the success of modern scientific investigations. Already, experimental research points to positive links between gender diversity and collective



Fig. 1. When it comes to science collaborations, there's ample data to suggest that gender diversity pays a substantial research and productivity dividend. Image courtesy of Dave Cutler (artist).

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The authors declare no conflict of interest.

Any opinions, findings, conclusions, or recommendations expressed in this work are those of the authors and have not been endorsed by the National Academy of Sciences.

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problem solving. In a study of group performance, Anita Woolley et al. (4) randomly assigned 699 participants to teams of varying sizes and asked them to solve a set of both simple and complicated tasks (e.g., visual puzzles, brainstorming, making collective moral judgments, and negotiating over limited resources). Through these experiments, the authors found evidence of a collective intelligence factor that predicts group performance better than the IQ of individual group members. Key components of this factor include the group members' social perceptiveness and parity in conversational turn-taking. Furthermore, gender plays an important role: women exhibit higher levels of social perceptiveness and teams with more women achieve greater equality in participation (4). The benefits of increasing women's representation, however, tend to flatten at the extreme (5). Neither all-men nor all-women teams are the most effective in problem solving. Hence, given the persistent gender gap in science, women represent an untapped potential for boosting the collective intelligence in scientific team work.

Recent discoveries in team science also highlight the importance of gender diversity for effectively using the expertise of each team member. Following 60 interdisciplinary teams of more than 500 scientists and engineers across a variety of disciplines, Aparna Joshi (6) shows that women more often than men accurately recognize the expertise of fellow team members. Based on two surveys—one gathering data about the participants' work-related and educational background, the other asking participants to evaluate fellow team members' research expertise—Joshi finds that women are more likely to emphasize educational qualifications when evaluating expertise, whereas men tend to be distracted by irrelevant cues, such as gender. By cultivating gender diversity, teams can overcome such biases and reap the full rewards of team expertise.

Gender diversity may also spark new discoveries by broadening the viewpoints, questions, and areas addressed by researchers. Two new large-scale studies shed light on this point[†]. Using topic modeling—a form of computational text analysis suitable for studying content variations in large samples of scholarly documents—a new study in management science finds that scholarly contributions written by women-dominated author groups typically pose different questions and engage in different research topics than men-authored studies. Articles with women authors are, for example, more likely to adopt critical and employee-centered perspectives on management, whereas men-dominated studies tend to be more prescriptive and operational in their focus.

*Börjeson L, Nielsen MW, Is there a gender-diversity dividend in management studies? National Science Foundation-funded workshop "Is there a gender-diversity dividend in science?" February 26, 2016, Stanford, CA.

[†]Nielsen MW, Andersen JP, Schneider JW, Does gender composition influence medical research groups' orientation towards gender and sex-based analysis? National Science Foundation-funded workshop "Is there a gender-diversity dividend in science?" February 26, 2016, Stanford, CA.



Fig. 2. This depiction of the mechanisms of innovation at scientific organizations emphasizes that “diversity in” does not automatically lead to “creativity out.” Maximizing gender diversity’s benefits requires careful management. Image courtesy of Erik Steiner (Stanford University, Stanford, CA).

Although pertaining to the realm of social science research, these findings raise intriguing questions of whether similar variations can be detected in science and engineering.

The second study uses computational text-mining tools and bibliometric data to tease out potential connections between women's level of participation in medical science and gender- and sex-related research. Understanding health-related physiological and behavioral differences between women and men is crucial in the diagnosis and treatment of many medical conditions. For example, sex differences in drug metabolism may lead to variations in patients' responses to medications. However, issues of gender and sex remain largely neglected in the medical literature. Controlling for variations across diseases, countries, and research areas, the second study detects a positive association between women's presence in the author byline and a study's likelihood of using gender- and sex-based analysis. Both studies illustrate how gender diversity can expand the general scope of knowledge production and add new perspectives to the current repertoires of possible management and health solutions.

Generating a gender-diversity dividend, however, is not simply a matter of how we populate teams and organizations, but also relates to how we deploy analytics to study the human condition. Incorporating methods of sex- and gender-based analysis into research design enhances the quality of scholarship and may save lives and money. In medicine, for example, one analysis found that 8 of 10 drugs withdrawn from the United States market between 1997 and 2000 posed “greater health risks for women than for men” (7), risks that could have been avoided if more attention had been devoted to gender and sex variation. State-of-the-art methods have been developed for overcoming such biases (genderedinnovations.stanford.edu). By analyzing gender and sex in all stages of the research process, from the initial considerations of problem choice to the development of methodological

design and data analysis, scientists may add important new dimensions to research.

Supportive Institutional Contexts

Taken together, the above-mentioned mechanisms grease the wheels of scientific discovery. The growing emphasis on teams in knowledge production, combined with women's educational gains in science and engineering, propel gender diversity to the forefront of promising new opportunities for scientific discovery. But what conditions need to be in place for organizations to fully realize such opportunities? There are approaches that can help establish more supportive institutional contexts, where both gender diversity and innovation thrive.

Effectively implemented policies are crucial for gender inclusion. However, some of the most widely

However, even flat structures are not effective unless the newcomers (women or underrepresented minorities) hit a critical mass, defined as representing between 15% and 30% of team members. Cindy Cain's and Erin Leahey's (10) systematic qualitative analysis of hundreds of autobiographical essays written by academic scholars in psychology, psychiatry, the life-sciences, engineering, and physics suggest that in fields where women have achieved a critical mass, they experience less stereotyping, more involvement in decision making and teamwork, and higher levels of support. Informal relationships move from being about "old boys' networks" to emphasizing connections, inclusiveness, and opportunities that likely benefit the scientific team and organization as a whole (10).

Scientific organizations can expedite the effects of critical mass by actively cultivating a positive climate for gender diversity. Lisa Nishii's employee survey of work climates in 100 units of a large United States biomedical company, for example, highlights the importance of fostering an open work culture that encourages all employees to freely express their cultural and gender identity on the job. Furthermore, her findings illustrate the benefits of actively encouraging an inclusive approach to decision making, where diverse insights and viewpoints are valued, even when challenging the status quo (11). Through dedicated leadership, these approaches can help reduce interpersonal bias and conflict while increasing employee satisfaction in teamwork. Women scientists' turnover rates will decrease and team science benefits as a result.

Recruiting women is not enough: Carefully designed policies and dedicated leadership allow scientific organizations to harness the power of gender diversity for collective innovations and discoveries. Put simply, we can't afford to ignore such opportunities.

Acknowledgments

These ideas and views emerged from a National Science Foundation-funded workshop held at Stanford University in February 2016.

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used diversity policy instruments have proven inefficient and sometimes even harmful in countering inequalities. In longitudinal analyses of more than 800 United States firms between 1971 and 2002, Frank Dobbin et al. (8) find that control instruments, such as performance ratings, job tests, and grievance systems—designed to prevent discriminatory behavior among managers—can have negative outcomes. In contrast, motivating managers to voluntarily engage in the recruitment and training of underrepresented groups better supports the advancement of women and minorities.

Research also demonstrates that women flourish in organizations with high degrees of cross-job communication and nonhierarchical structures. Based on career information of more than 2,000 United States life scientists, Laurel Smith-Doerr (9), for example, finds that women are nearly eight times more likely to lead research projects in biotech firms with flat job-ladders than in more hierarchical academic and pharmaceutical settings.

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