Addressing the leaky pipeline through mentoring and support: a personal perspective

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Materials research is poised to play a pivotal role in addressing the grand challenges faced by society, from engineering better medicines to providing accessible clean water and renewable energy. However, complex problems require diverse teams. Therefore, there is an urgent need to address the diversity gap in materials science and engineering, especially for women.

The imperative of diversity

Teams benefit from diversity in terms of scientific discipline, gender, ethnicity and background (for example, prior experiences and nationality) to produce innovative solutions to complex problems. In particular, gender diversity plays a key role[1]. However, diverse talent — especially women — are lost from the science, technology, engineering and math (STEM) pipeline at all levels of training, from elementary through to postgraduate training (FIG. 1). Currently, women comprise approximately half of the US college-educated workforce, but only ~29% of the STEM workforce. Similarly, under-represented minorities represent 27% of the US working age population, but only 11% of the STEM workforce (National Science Foundation (NSF), Science & Engineering Indicators, 2016). Therefore, addressing the leaky pipeline and diversity in STEM is the focus of many efforts across disciplines[2,3]. In this Comment, I investigate the leaky pipeline at more junior levels, including trainees and junior professionals, based on my experiences as a woman in STEM: once a first-generation college student and now recently tenured faculty member, who mentors a diverse group of trainees. I discuss opportunities for supporting the careers of people from all backgrounds based on my observations of successes and barriers that constitute sources of leaks in the middle of the pipeline, highlighting the pivotal importance of mentoring and support for a career–life balance.

Mentoring

The need for mentoring in shaping the work and ambition of new comers into a directed strategy has been highlighted in the popular press and scientific literature. From Sheryl Sandberg's *Lean In* to Anthony Tjan's *Good People*, insights have been provided into the multiple types of mentors and mentoring that are needed for success. For example, Tjan outlined how trainees or mentees benefit from establishing genuine relationships with individuals who are a 'master' within a specific area of expertize (a role model and trainer), a 'champion' (a sponsor or advocate), a 'co-pilot' (a peer mentor or collaborator), an 'anchor' (someone outside the field who can be a sounding board and confidant) and a 'reverse mentor' (who can offer a fresh perspective and feedback on mentoring)[4].

Masters and champions who are well established in academic or industrial positions, as well as co-pilots, are crucial for shaping career paths and retaining talent from diverse backgrounds. Such mentoring is especially important for individuals from non-traditional paths (for example, first-generation college students or people from under-represented groups) at early stages of training for gaining access to information about the plethora of opportunities. At later stages of training, pair-wise engagement between mentees and masters, champions and co-pilots can support specialization within a discipline. Institutions must invest in both top-down and grass-roots programmes to connect mentors and mentees with specific and complementary experiences, expertize and interests and foster a culture of success for all individuals.

Undergraduate level. Engaged faculty in the classroom are pivotal for student training and mentoring. As an undergraduate at North Carolina State University (NCSU), I had the pleasure of taking courses held by a number of talented faculty, including Richard Felder, who is a leader in engineering education. As with most introductory STEM courses, material and energy balances at NCSU have high attrition; however, Felder, among others, was committed to providing opportunities for engagement and learning. For example, he practiced and advocated for addressing the different ways that people learn, including sensing, visual, active and sequential learning. Building small and diverse teams of students for both in-class and homework assignments

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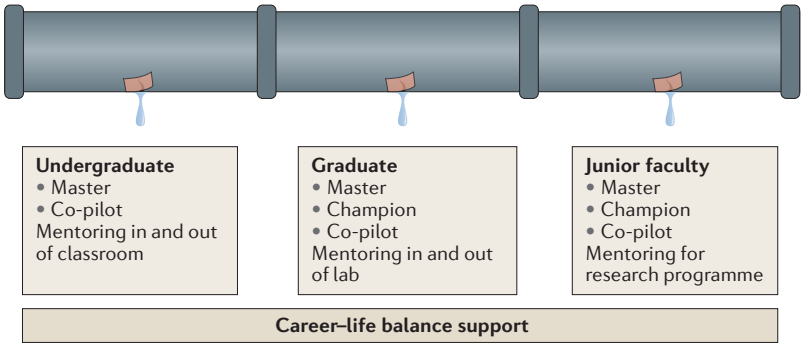

Fig. 1 | **Addressing the leaky pipeline.** The leaky pipeline can be addressed through mentoring at all stages of training.

enabled learning through peer mentoring by assigning co-pilots. He also developed and implemented educational tools, for example, a post-exam 'memo', providing a checklist to help students assess what may have gone wrong in their preparation for the exam to empower them to learn how to learn[5]. This mentoring was particularly important for me as a first-generation college student to answer questions such as did an individual disparity or failure mean that I should not be here? This impostor syndrome — believing that accomplishments are just luck or deceit — can be dispelled by acknowledging its existence to realize that almost everyone (incorrectly) feels like an impostor at some point in their career[6,7]. Peer mentoring outside the classroom is vital in addressing this challenge; for example, through social and networking events, conference trips, tours of local production facilities and presentations from local and national industrial masters, valuable relationships can be built that provide a sense of comradery and community, and professional societies play an important role in this, for example, student, local and regional chapters of American Institute of Chemical Engineers (AIChE), American Chemical Society (ACS) and Materials Research Society (MRS). Institutional investment in faculty training and specialization in teaching and mentoring as well as support structures for grassroots peer mentoring are needed to catalyse and guide student-run organizations and to create a vibrant community with a critical mass of individuals who are traditionally under-represented.

Graduate level. At the graduate level, champions become increasingly important in addition to continued engagement of masters and co-pilots, and, most importantly, the research adviser (in my case, the exceptional scientist, teacher and mentor Kristi Anseth at the University of Colorado). The selection of advisers is often primarily driven by the research project and topic; however, a good fit between the mentor and mentee is equally important, and if successful, the relationship can transition to the stages of co-pilot, anchor and reverse mentor over the course of a career. The research adviser guides the student in goal setting for research and careers and provides resources for success, ranging from funding to support of applications for fellowships and awards. Beyond pair-wise interactions, a faculty adviser in conjunction with student co-pilots also establishes and maintains the culture of the research group to support individual and communal success, including research progress, education and career development (for example, science communication and networking before and after graduation in the community and within the growing academic family tree), as well as peer mentoring.

Traineeship programmes. Traineeship programmes and dissertation committees are important for further establishing the department and university ecosphere that shapes and enables trainee success, providing an array of masters, champions and co-pilots with different experiences and expertize. Programmes that allow students to serve as co-instructors for a course enable them to hone their technical and communication skills and to directly interact with faculty mentors outside of their research group. For example, the Fraser and Shirley Russell Teaching Fellows programme at the University of Delaware has supported a large number of leaders in academics and industry[8]. Similarly, at the University of Colorado, I worked with extraordinary mentors in the classroom; for example, during my advanced teaching assistant position I co-instructed a course with John Falconer (leader of the National Science Foundation (NSF)-funded LearnChemE initiative). These experiences were crucial for me to learn how to become an effective teacher and faculty member, and to overcome the anxiety I felt for public speaking.

Interdisciplinary traineeship programmes can create a diverse community of graduate trainees and faculty trainers (for example, Department of Education Graduate Assistance in Areas of National Need (GAANN) Program, National Institutes of Health (NIH) Chemistry–Biology Interface (CBI) Program and NSF Integrative Graduate Education and Research Traineeship (IGERT) Program, which I have been a part of as a trainee and now as a trainer). The connections with co-pilots can be essential in forming a robust, self-sustaining student community that helps students overcome hurdles during their training, for example, research challenges, effective communication, work–life balance and impostor syndrome.

Junior faculty. For trainees transitioning to trainers, professional societies (such as ACS and AIChE) and grant programmes with mentoring (such as Pew Scholars Program in Biomedical Science, NIH-funded K99/R00 or Centers of Biomedical Research Excellence) can provide similar types of formal and informal master and co-pilot mentoring to support junior faculty. For example, in the polymeric materials and biomaterials communities, several symposia, sessions and workshops have been initiated to celebrate the successes of junior faculty or to aid in the training to become a faculty member (for example, ACS Polymeric Materials: Science and Engineering (PMSE) Outstanding Young Investigator Symposium, NSF Chemistry Early Career Investigator Workshop, AIChE Materials Engineering & Sciences Division (MESD) Biomaterials Future Faculty session as well as Women's Initiative Committee (WIC)

workshops and networking events and NSF-funded Future Faculty Workshop). More formal programmes are also available, such as the National Center for Faculty Development and Diversity that provides opportunities for engagement, including online webinars and workshops as well as an in-person Faculty Success Program and Bootcamp. Engaging with or adapting these models across agencies could prove useful in recruiting and retaining a diverse faculty.

Career–life balance initiatives

Strategies and support for achieving a career–life balance are needed at the trainee and early career trainer levels to enable individuals to 'lean in' while maintaining healthy lifestyles, including relationships with others; in particular, direct and indirect support for individuals experiencing life-changing events, such as the birth or adoption of a child or care of an elderly parent. Many trainees and trainers exit the work force or can suffer short-term and long-term consequences as a result of being away from work owing to a lack of access to good and affordable child care (or elderly care), which has statistically resulted in an increase in the pay gap between women and men[9]. Importantly, trainees also may leave the work force owing to the perception of such challenges, expecting a crossroads between certain life experiences (for example, having a family) and high achievement in STEM.

To address this imbalance, improved access to family care is needed, for example, by providing institutional support and by subsidizing routine childcare, emergency childcare and elderly care. These services should be viewed as a benefit for recruitment, retention and success rather than as independent cost centres. For transient care needs, formalized access to contract care services (such as Care) can supplement on-going daily services, for example, during travel or acute illness. Beyond support of family care programmes, additional transient support is needed to help faculty with running their labs during these events; for example, by supporting a postdoctoral researcher or technician during the event to allow maintenance of the research group. Initiatives such as the NSF CAREER program Career–Life Balance Supplement could be implemented at institutions and in other funding agencies. Finally, access to short-term leave and the possibility to 'stop the clock' for promotion and tenure need to be officially and unofficially supported for both women and men to ensure that people do not feel stigmatized for taking time off. Such policies would also show trainees that working in STEM is not incompatible with family life and can even provide beneficial opportunities (for example, flexitime).

Summary

There are many factors that influence recruitment and retention in STEM fields. Support structures within and across fields that promote mentoring and career–life balance provide opportunities to foster the success of early career STEM trainees and trainers. Improving the work environment and promoting the success of all people will help to cultivate and grow the next generation of diverse leaders in STEM. Executing small changes as individuals and engaging as mentors, mentees and human beings in and out of the classroom and lab will enable us to address the leaky pipeline and tackle the grand challenges that face society.

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Competing interests

The author declares no competing interests.

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ACS: https://www.acs.org/content/acs/en/membership-and-networks/acs/welcoming/industry/networking.html
ACS Polymeric Materials: Science and Engineering (PMSE) Outstanding Young Investigator Symposium: https://pmsedivision.org/pmse-young-investigator/
AIChE: https://www.aiche.org/resources/careers/networking-opportunities
AIChE Materials Engineering & Sciences Division (MESD) Biomaterials Future Faculty session: https://aiche.confex.com/aiche/2018/meetingapp.cgi/Session/38607
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Centers of Biomedical Research Excellence: https://www.nigms.nih.gov/Research/DRCB/IDeA/pages/COBRE.aspx
Chemical Engineering Summer School: http://www.chesummerschool.org/; http://ched.asee.org/summer-school/
Department of Education Graduate Assistance in Areas of National Need (GAANN) Program: https://www2.ed.gov/programs/gaann/index.html
Impostor syndrome: http://www.sciencemag.org/careers/2008/02/no-youre-not-impostor
LearnChemE initiative: http://www.learncheme.com/
MRS: https://www.mrs.org/
National Center for Faculty Development and Diversity: https://www.facultydiversity.org/
National Effective Teaching Institute: https://www.asee.org/education-careers/continuing-education/courses-and-workshops/neti
National Institute of Health (NIH) Chemistry–Biology Program: https://www.nigms.nih.gov/Training/InstPredoc/Pages/PredocDesc-Chemistry.aspx
National Science Foundation (NSF), Science & Engineering Indicators, 2016: https://www.nsf.gov/statistics/2016/nsb20161/#/
NIH K99/R00: https://researchtraining.nih.gov/programs/career-development/k99-r00
NSF CAREER program Career-Life Balance Supplement: https://www.nsf.gov/career-life-balance/
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NSF-funded Future Faculty Workshop: https://sites.udel.edu/future-faculty-workshop/
Pew Scholars in Biomedical Science: https://www.pewtrusts.org/en/projects/pew-biomedical-scholars
Women's Initiative Committee (WIC) workshops and networking events: https://www.aiche.org/community/sites/committees/women-in-chemical-engineering