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TEACHING TIPS

Rethinking the Responsible Conduct of Research (RCR) Course

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Abstract

Responsible Conduct of Research (RCR; also referred to as Responsible and Ethical Conduct of Research) courses are required for students funded by NIH training grants or NSF awards. Most university RCR courses closely follow the list of topics described by the NSF/NIH and use the low-effort, distributed teaching model described by the NIH. Recommended topics include research misconduct, data management, authorship, peer review, conflicts of interest, intellectual property, mentor/mentee relationships, collaboration, safety and regulatory processes, and ethics. While these topics prepare the student to become a responsible researcher, we also considered our responsibility as a department to provide students with tools to succeed. Specifically, we wanted this course to (1) build community, (2) provide students with skills to face challenges associated with graduate school, and (3) prepare the student to start their research project. To accomplish these goals, we incorporated additional topics and used an instructional model with a central instructor supported by faculty discussants during a subset of classes. The result is a course that is compatible with funding agency requirements but also helps to build a stronger community and formalize aspects of training that do not easily fit within technical courses.

Keywords Engineering education · Cohort building · Onboarding · Wellness · Scientific writing instruction

Challenge Statement

Over the past five years, the BME PhD program at the University of Wisconsin-Madison redesigned its coursework and examinations. At the core of this shift was a recognition that BME straddles the interface between biology and engineering. While our prior requirements reflected a traditional engineering approach and were content heavy, our new approach is more aligned with modern biology programs that emphasize research productivity as the core outcome of the PhD (by research, we are referring to a student's thesis work and other original scholarship). We examined the curriculum of other graduate programs at the University of Wisconsin-Madison and found that while 100% ($n = 11$) of biology programs require an RCR course of all students, only 25% ($n = 8$) of engineering programs did. Since RCR training is mandated for all students on NIH training grants or receiving NSF funding, we decided to add a RCR requirement for all BME PhD students.

While several RCR courses already existed, we sought to develop a BME-specific course with two core objectives. First, the course needed to meet both NIH and NSF requirements as we have trainees on both funding sources. Second, we wanted to meet the department's responsibility to prepare students for independent research. While there are many sub-skills that are best left to an individual development plan (IDP, [1]), we identified three higher-level areas for the course to support.

- Develop a collegial and interactive departmental community: As a highly inter-disciplinary program, BME students may have minimal overlap in their coursework with their cohort. Additionally, our students conduct their research in labs across campus through a network of primary and affiliated faculty. While this specialization is advantageous for research, it does not easily foster community, a feature of graduate programs that correlates with student retention [2, 3].

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- Discuss tools to deal with some of the challenges associated with graduate school: It has been well documented that depression and anxiety are higher in the graduate student population compared to their age-matched peers [4]. Additionally, recent stories have made clear that bias and harassment continue to be issues in the scientific community [5–7].
- Provide conceptual frameworks for original research: Without diving into details, we wanted students to think about how to develop and explain their research question. In addition, we wanted to students to understand how the core RCR content relates to their own work.

Novel Initiative

To develop the course, we began with NIH and NSF guidance on RCR. At the time of course development, NIH guidance included nine topics (Fig. 1, [8]). NSF guidance leaves the specific topics to the university to decide, but emphasizes peer review, intellectual property, and the responsibility to "treat students and colleagues fairly and with respect" [9].

Course Format

We first considered the course format. NIH guidance emphasizes that RCR should be a discussion-based course with faculty participation. This is often implemented as a low-effort model where for each topic a small number of faculty attend the course and participate in group discussions on case studies. In our analysis of University of Wisconsin-Madison graduate programs, 83% of the graduate programs that required a RCR course use this distributed model (n = 12, one program did not clearly specify). Our observation had been that student engagement in this model is often low, which we reasoned could result from 1) lack of familiarity with the material or 2) not feeling comfortable to talk openly with the other discussants, including faculty whom they do not know. To address both concerns, the class format was expanded from a standard, one-time per week RCR to a twice weekly meeting (50 minutes per meeting, 2 credit course). The additional class sessions were used for discussions led by the primary instructor. These discussions were more content focused, with a set of notes distributed to the students as a guide for the day. For a subset of topics, the primary instructor was joined by two additional faculty members to lead group discussions of case studies (Fig. 1). Case studies were selected from multiple sources including the instructor's experiences and online resources from other RCR courses. The faculty discussants both satisfied NIH guidance and fit with our departmental responsibility to build community [11, 12]. To encourage engagement, student grades were partially based on attendance and participation.

To build a cohort, the course was required for all PhD students during the first fall semester of their PhD training. Due to students transitioning from MS or MD coursework, this did not always coincide with their first semester on campus. We placed the topics into four modules (Fig. 1): onboarding students to start research, traditional RCR topics related to working in laboratories, communication of research results, and building a better scientific community.

Module	Topic	Fulfills	Discussion section	Advisor assignment
Getting started in a PhD	Graduate school is not undergraduate 2.0			
	Safety and regulations	NIH - b		✓
	Mentor and mentee expectations	NIH - c	✓	✓
	Identifying research problems			✓
	Wellness			
Working in research	Data management	NIH - f	✓	✓
	Animal and human subjects	NIH - b	✓	✓
	Conflict of interest	NIH - a		
	Intellectual property	NSF - b		
	Research misconduct	NIH - g	✓	
	Collaboration	NIH - d		
Sharing results	Authorship	NIH - h		
	Scientific narrative			
	Peer review	NIH - e, NSF - a		
	Scientific communication			
Making science better	Culture and climate in science	NSF - c *	✓	
	Ethics	NIH - i	✓	
	What comes next?			

Fig. 1 Organization of RCR course. Topics that are included in NIH or NSF descriptions of RCR are noted with the letter corresponding to these lists [8, 9]. We organized these subjects into four modules with at least one instructor-led class for each topic (except for ethics) and additional discussion classes where noted. A subset of topics had assignments where students needed input from their advisors. *NIH has updated guidelines (NOT-OD-22-055, [10]) with expansion of prior topics and the addition of 'safe research environments... those that promote inclusion and are free of sexual, racial, ethnic, disability, and other forms of discriminatory harassment.'

Some topics were given substantially more time due to student interest; for example, peer review expanded to a three-session discussion that covered different forms of peer review, confidentiality issues, how peer review differs for papers vs. grants, bias in review, and how to respond to reviews.

To build community between the instructor and students, each day started with an ice breaker question posed by either the instructor or solicited from the students. Example questions included favorite holiday, favorite dessert, last live music event, and superpower you would most want to have. An obvious concern was to make these questions inclusive. As the instructor, it was helpful to model extended answers—rather than just saying that the last concert was the Foo Fighters, we would provide a couple of additional sentences on what was interesting about that experience. This subtly encouraged students to follow the example and share more with their peers. When additional faculty participated in group discussions, they were asked to introduce their research interests and participate in the ice breaker. Sharing something personal seemed to lessen the perceived gap between instructor and student.

Most instructor-led days had short pre-readings assigned to provide background information and homework was assigned each week. To support onboarding, many of the early assignments required the student to seek out their advisor or senior lab members. For example, for mentor–mentee expectations, the student had to find the lab expectations document (a departmental requirement, see [13] for suggestions on developing one) and identify three points they wanted the advisor to clarify.

New Topics in Support of Departmental Responsibilities

Demystifying the graduate experience: This topic was split between the first and last sessions of the class. During the first session, the instructor gave an overview of the graduate program expectations, held an open-ended discussion of how graduate training differs from other education, and provided suggestions on how to plan out the PhD years. The final session returned to the graduate program timeline, discussed funding opportunities, outlined what goes into an individual development plan, and detailed professional development opportunities on campus.

Identifying research problems: It goes without saying that identifying a thesis research question is an essential task and the process to do so can be challenging. However, the obviousness of that statement to a faculty advisor is sometimes not apparent to a student who is struggling with their first foray into truly unknown science [14]. A useful schema for this stage is Alon's 'cloud' [15], where results do not make sense with our intuition and require us to find new knowledge. Our experience suggested that most students deal with an additional 'cloud,' where the results do not make sense due to errors in experimental design and execution (Fig. 2). Strategies to minimize time in 'cloud 1' (experimental issues) were discussed, as well as mechanisms to gain support for the frustration of 'cloud 2' (conceptual understanding).

Wellness The instructor presented students with information about mental health challenges associated with graduate school and resources available on campus. Students were asked to speculate on why the rates of depression and anxiety are higher [4] and then discussed strategies to counteract the potential causes (*e.g.,* isolation, long hours, advisor/colleague interactions). A framework for wellness was presented that encouraged students to think about a toolset that they can use to help them through challenges [16]. Students were assigned to develop a wellness collage with things that they enjoy and shared one item from that collage with the class during an icebreaker.

Scientific Narrative Writing and presenting for the scientific audience is a challenging but essential skillset for research-based careers [17]. As it was impossible to teach everything involved in these skills in a multi-topic course, we provided an overview of the structure and organization of the scientific narrative as defined by the Scientific Communication Advances Research Excellence (SCOARE, [18]). This schema defines the components used to communicate science as the Gap, Purpose, Approach/Methods, Results, Conclusion, Significance, and Implications. Students were encouraged to apply this schema to papers they read to see it implemented, as well as their own project to break the big question (Gap) into more specific elements (Purpose and

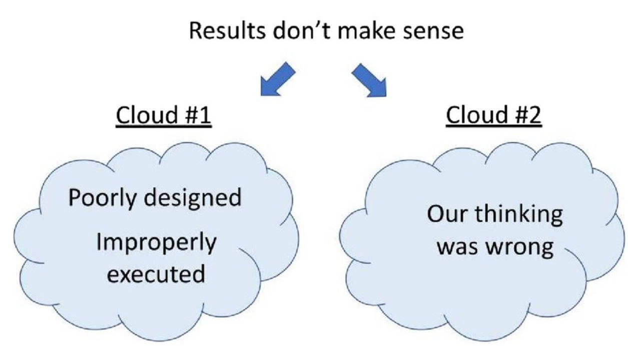

Fig. 2 Schema for dealing with a scientific roadblock. When results do not make sense, it can result from two different sources. The first cloud is technical errors (*e.g.,* improper controls, technical errors, inexperience with methods). Time spent in cloud 1 is common and can eventually be minimized with the acquisition of sufficient training. The second cloud is conceptual challenges (*e.g.,* predictions based on prior knowledge that do not apply to this question). Times spent in cloud 2 is frustrating and potentially isolating, but essential for development of new scientific knowledge.

Approach/Methods). We then briefly covered figure preparation to clearly convey the 'story' of the data [19] and discussed citation practices [20].

Scientific Communication The COVID-19 pandemic demonstrated that scientists need to learn how to communicate better with the general public. Various goals, formats, and audience considerations associated with scientific communication were discussed and students were assigned to explain their project in the form of a 'lay abstract,' pick an interesting paper and develop a 'tweetorial,' select a paper from their lab and write a news brief, or develop a gif of a scientific concept.

Culture and Climate of Science While science is often portrayed as a pure, unbiased pursuit, scientists are human beings and subject to all the flaws that this entails. As a human undertaking, science has a culture – a set of values and principles that set up the norms. The scientific culture has always been competitive, whether the competition has been to be the first to achieve some goal or to procure the resources needed to do the work. Additionally, while most scientific pursuits require the skill and effort of many, the scientific culture often credits one 'genius' individual who possessed a near single-minded focus on their work (*e.g.*, Oppenheimer vs. the entire Manhattan Project). This culture still dominates and results in a climate that discourages many from research-based careers. Given the importance of this topic, elements were distributed across the course.

First, during our mentor/mentee expectations discussion, we considered the power dynamics of the academy, where professors have control over a student's progress to degree, stipend, and/or visa status [21]. This differential remains even after the student has earned their doctorate, as future positions may ask for letters of recommendation from the thesis advisor/committee members. We considered that mentoring relationships could be 'good' (*i.e.,* positive, supportive, well-aligned styles), 'sub-optimal' (*i.e.,* a relationship that is not a good match for the two individuals in question, but the same interaction could be 'good' for another pairing) and 'toxic' (*i.e.,* relationships where bullying or harassment occurs). The topic of 'toxic' mentorship was also discussed in relation to mental health and wellness. It was decided that specific incidents from our own college would be acknowledged [22] and discussed to make clear this can be a problem anywhere and will not be ignored in our department.

Second, we considered that science has historically been a mostly male, mostly white culture. This is reflected today in the form of funding discrepancies [23], bias in review [24], and citation gaps [25], which were discussed during the peer review and scientific narrative sessions. In addition, many scientists deal with the effects of racism, sexism, xenophobia, homophobia, transphobia, and/or ableism daily in their work environment through harassment [26], gaslighting [27], and subtle acts of exclusion [28]. It was our opinion that turning a blatant harasser into a positive member of the scientific community was beyond our abilities (and possibly beyond hope). Therefore, the curriculum focused on culture and climate in order to 1) increase awareness of the larger issues and 2) develop skills for students to recognize, counter, and support those experiencing harmful behavior. Using resources from the NIH OITE [29], we discussed the roles of perpetrator, victim, bystander, and upstander. We considered what the person in each role could do once they recognized a harm had been done and provided tools that a bystander can use to become an upstander [30]. Finally, we discussed the grievance process within the department.

Reflection

We first consider the changes made to the traditional RCR course and then examine whether these changes helped to meet our departmental responsibility to 1) build community, 2) provide skills to face the challenges associated with graduate school, and 3) prepare the student to start their research project.

Course Format

The course was developed and offered for the first time in Fall 2020 during the second academic semester of the COVID pandemic and was entirely virtual. While students regularly attended, discussions were limited, and many students relied on the chat feature to engage. During the second offering in Fall 2021, the campus was under a mask mandate for indoor courses, so the class met outside until the middle of October. Most students chose to be unmasked in the outdoor sessions, and discussion was robust with no noticeable change upon returning to indoors and full masking. In the third offering in Fall 2022, the class was indoors, and most students chose to be unmasked. Despite having the largest enrollment (21 students), discussion was strong and balanced across many students.

One major difference from most RCR courses was that most days were instructor led. We emphasize that instructor-led days were not lectures; the instructor sat in a chair and led the students through the notes while asking open-ended questions and taking comments/questions, which counted toward the participation grade. Students generally agreed that both formats were effective, with only a slight preference for instructor-led days (Fig. 3). In comparison to other RCR courses where we have been faculty discussants, the students seemed much more engaged during group discussion which may reflect the additional familiarity with the

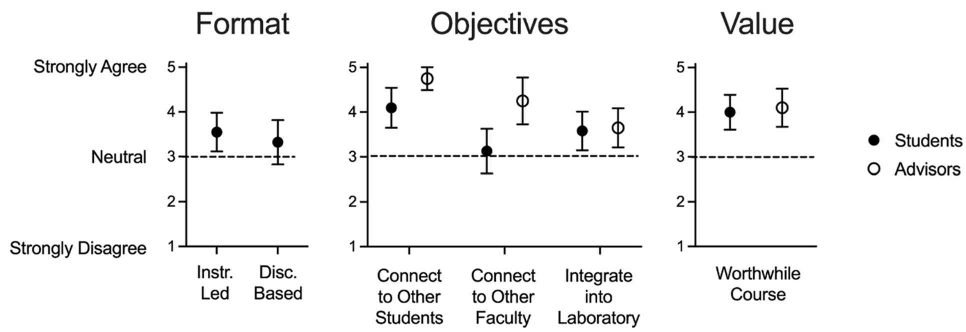

Fig. 3 Survey of RCR students and their advisors. We contacted students enrolled in the first three offerings of the new RCR course and their faculty advisors and asked them to do a short survey. The response rates were 63.3% from students and 83.3% from advisors. Answers were scored ranging from "1—strongly disagree" to "5 – strongly agree." Shown are the average ± 95% confidence interval (*n*= 31 for students, 20 for advisors); agreement is indicated when the error bars do not cross the neutral line at 3, p<0.05 by a one-sided t test. This survey was certified as constituting QI/Program Evaluation and therefore does not require IRB review.

topic. This was also commented on by faculty who participated as discussants, "very interactive and good engagement by students" and "discussions were engaging and I could tell the students were developing important critical thinking skills."

Community Building

Students and faculty were asked about the impact of this course on the student making connections with other BME students and faculty. Both groups agreed that the course helped to build peer connections (Figure 3). The impact of course format was most obvious here, as the scores from Zoom students were significantly lower than in person (2.8±1.2 vs. 4.6±0.8, p = 5e-5 for t test, $n = 8$ and 23, respectively). Peer connections were apparent in the in-person semester, with students discussing challenges they had in lab that week, gathering after class to work on homework in small groups, and making social plans. The daily ice breakers and the wellness collage assignment appeared to foster connections between students as they shared the sports, music, animals, and other sources of joy in their lives. Faculty agreed that the course helped to build connections for their student with other faculty, while the student response was neutral. We suspect this discrepancy partially results from faculty making comparisons to prior students who did not participate in this course. However, one limitation with the current design was that on group days the primary instructor still served as a discussion leader, meaning that even with a mid-class rotation only one third of the class interacted with both guests. In future offerings, the instructor could leave after taking attendance and setting up the activity so that interactions with new faculty are maximized. This might require more guest instructors to maintain a small group size.

Culture and climate were added in response to concerns raised in our department, campus, and the broader BMES community. This topic was also selected as it is consistent with the NSF recommendation that RCR includes a responsibility to "treat students and colleagues fairly and with respect" [9]. While a potentially challenging topic, it appeared to foster community building, with open, honest, and respectful discussions about how to make amends when you were the perpetrator or how to move from bystander to upstander. Some students voluntarily contributed their experiences as the victim; this was met with support from the other students. We note that discussion of harassment is now recommended explicitly in the updated NIH guidelines [10].

Facing the Challenges of Graduate School (and Beyond)

Many of the topics that were added reflected discussions among faculty about how to help students transition from undergraduate to graduate work – helping them to find an appropriate balance between coursework and research time, learning how to think independently about their projects, building their writing skillset, and taking charge of their career path. As one student reflected, "The course introduced us to the many variables present when pursuing a PhD and helped establish a foundation for how to navigate the situations, conversations, relationships, lab dynamics, etc. which I have encountered so far."

Preparation to Start Research

To determine if students and advisors found the course useful for the student to start their PhD, we asked if the assignments where students checked in with their advisor helped them to integrate into the laboratory. Both students and faculty agreed that these activities were useful (Figure 3). The positive response also suggests that these activities were not too time intensive or logistically challenging (students were allowed to use email or in person meetings to complete the assignment). One advantage of this approach was that it streamlined programmatic check-ins. For example, all faculty are required to have an expectations document for their advisees. By having all new graduate students request and turn in this document, the graduate chair easily confirmed faculty compliance. An additional benefit of these assignments was that they shift some responsibility for regulatory compliance to the student as they must identify what is needed vs. wait for the advisor to tell them.

Given time constraints, there are additional topics that were not included but would be appropriate if expanded to a three-credit version. In particular, we would like to expand and include time management strategies and how to give/use constructive feedback. While individual development plans were discussed in the course, adding an assignment to move from broad goals to a specific plan through the SMART structure may be useful [31]. It will also be important to expand some of the existing topics to keep compliant with updates to NIH and/or NSF guidelines. For example, we discussed collaboration primarily within our university or with companies, but the new guidelines emphasize international collaborations which require consideration of additional policies.

Overall Evaluation

Both students and advisors found the course to be worthwhile (Figure 3), with average scores of 4.0 and 4.1 out of a possible 5. Student reflections included "Great course. It definitely enriched my PhD experience and equipped me with many soft skills necessary for graduate school" and "The course helped a lot with the topics, definitely recommended to take." Course preparation was heaviest the first year but built primarily from workshops and articles that had been accumulated over a decade of mentoring. As the instructor, we found it enjoyable to interact with the students, discuss the research process, and reflect on how a student develops into a PhD-level researcher.

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Authors Contributions PKK developed and taught the first three offerings of the course, conducted the survey, and wrote the manuscript.

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Data Availability Data are available from the corresponding author upon reasonable request

Declarations

Conflict of interest The author has no conflict of interest to disclose.

Ethical Approval The survey discussed is classified as quality improvement and not research; therefore it is not subject to IRB review.

Consent for Publication The author hereby provides *consent* for the *publication* of the manuscript detailed above, including any accompanying images or data contained within the manuscript.

Competing interests Not applicable

References

1. Clifford PS. Quality time with your mentor: students and mentors should agree on a development pan that clearly delineates career goals and establishes a strategy for additional skill acquisition. (Fine Tuning). Scientist. 2002;16(19):59–60.
2. Lovitts BE, Nelson C. The hidden crisis in graduate education: attrition from Ph.D. programs. Academe. 2000;86(6):44.
3. Fenning K. Cohort based learning: Application to learning organizations and student academic success. Coll Q. 2004;7:n.1.
4. Evans TM, Bira L, Gastelum JB, Weiss LT, Vanderford NL. Evidence for a mental health crisis in graduate education. Nat Biotechnol. 2018;36:282–4.
5. Wadman M. NYU may hire biologist pushed out of MIT. Science. 2022;376(6592):444.
6. Perry N. Women working in Antarctica say they were left to fend for themselves against sexual harassers. New York: Associated Press; 2023.
7. Larson C. Black scientists call out racism in the field and counter it. New York: Associated Press; 2020.
8. NIH, Update on the Requirement for Instruction in the Responsible Conduct of Research, 2019. https://grants.nih.gov/grants/guide/notice-files/not-od-10-019.html
9. NSF, Responsible and Ethical Conduct of Research. https://www.nsf.gov/od/recr.jsp
10. NIH, FY 2022 Updated Guidance: Requirement for Instruction in the Responsible Conduct of Research, 2022. https://grants.nih.gov/grants/guide/notice-files/NOT-OD-22-055.html
11. Weidman J, Stein E. The socialization of doctoral students to academic norms. Res High Educ. 2003;44:641–56.
12. Venkatesh MJ, Elchert AR, Fakoya B, Fernandez F, Kwong AC, Liu YJ, Lotfy P, Lowe DD, Petty CA, Rodriguez-delaRosa A, Seguinot BO, Shi Y, Loparo JJ. More than just content: building community in the graduate classroom. Nat Biotechnol. 2021;39:1161–5.
13. Masters KS, Kreeger PK. Ten simple rules for developing a mentor-mentee expectations document. PLoS Comput Biol. 2017;13:e1005709.
14. Schwartz MA. The importance of stupidity in scientific research. J Cell Sci. 2008;121:1771.
15. Alon U. How to choose a good scientific problem. Mol Cell. 2009;35:726–8.

16. NIH OITE, Becoming a Resilient Scientist Series (Part 1): An Introduction to Resilience & Wellness [Video]. [Video], YouTube, 2021. https://www.youtube.com/watch?v=XHeEBFBP2Zs
17. Cameron C, Lee HY, Anderson CB, Trachtenberg J, Chang S. The role of scientific communication in predicting science identity and research career intention. PLoS ONE. 2020;15:e0228197.
18. Dahlstrom EK, Bell C, Chang S, Lee HY, Anderson CB, Pham A, Pribbenow CM, Cameron CA. Translating mentoring interventions research into practice: evaluation of an evidence-based workshop for research mentors on developing trainees' scientific communication skills. PLoS ONE. 2022;17:e0262418.
19. Rougier NP, Droettboom M, Bourne PE. Ten simple rules for better figures. PLoS Comput Biol. 2014;10:e1003833.
20. Penders B. Ten simple rules for responsible referencing. PLoS Comput Biol. 2018;14:e1006036.
21. Williams MR, Hendricks M. Professor used students as servants. UMKC knew and didn't stop him, The Kansas City Star, 2018.
22. K. Meyerhofer. UW-Madison engineering professor who led 'toxic' lab will resign this summer. Wisconsin State Journal. 2021.
23. Stevens KR, Masters KS, Imoukhuede PI, Haynes KA, Setton LA, Cosgriff-Hernandez E, Lediju Bell MA, Rangamani P, Sakiyama-Elbert SE, Finley SD, Willits RK, Koppes AN, Chesler NC, Christman KL, Allen JB, Wong JY, El-Samad H, Desai TA, Eniola-Adefeso O. Fund Black scientists. Cell. 2021;184:561–5.
24. Silbiger NJ, Stubler AD. Unprofessional peer reviews disproportionately harm underrepresented groups in STEM. PeerJ. 2019;7:e8247.
25. Dworkin JD, Linn KA, Teich EG, Zurn P, Shinohara RT, Bassett DS. The extent and drivers of gender imbalance in neuroscience reference lists. Nat Neurosci. 2020;23:918–26.
26. Berhe AA, Barnes RT, Hastings MG, Mattheis A, Schneider B, Williams BM, Marín-Spiotta E. Scientists from historically excluded groups face a hostile obstacle course. Nat Geosci. 2022;15:2–4.
27. Platt MO. We exist. We are your peers. Nat Rev Mater. 2020;5:783–4.
28. Jana T, Baran M. Subtle Acts of Exclusion: How to Understand, Identify, and Stop Microaggressions, Berrett-Koehler Publishers2020.
29. NIH OITE, Moving from bystander to upstander: take action to combat harassment and aggression. [Video], NIH Videocast, 2020. https://videocast.nih.gov/watch=37765
30. Borrero-Mejias C, Starling AJ, Burch R, Loder E. Consortium migraine mavens writing, eleven things not to say to your female colleagues. Headache. 2019;59:1846–54.
31. Flood AH, Skrabalak SE, Yu Y. Individual development plans—experiences made in graduate student training. Anal Bioanal Chem. 2021;413:5681–4.