COMMENTARY

Improving research integrity: a framework for responsible science communication

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Abstract
Research integrity, an essential precept of scientific inquiry and discovery, comprises norms such as Rigor, Reproducibility, and Responsibility (the 3R’s). Over the past decades, numerous issues have arisen that challenge the reliability of scientific studies, including irreproducibility crises, lack of good scientific principles, and erroneous communications, which have impacted the public’s trust in science and its findings. Here, we highlight one important component of research integrity that is often overlooked in the discussion of proposals for improving research quality and promoting robust research; one that spans from the lab bench to the dissemination of scientific work: responsible science communication. We briefly outline the role of education and institutions of higher education in teaching the tenets of good scientific practice and within that, the importance of adequate communications training. In that context, we present our framework of responsible science communication that we live by and teach to our students in courses and workshops that are part of the Johns Hopkins Bloomberg School of Public Health R3 Center for Innovation in Science Education.

Keywords: Research integrity, Rigor, Responsibility, Scientific communications training, Institutional graduate education programs

Introduction
Science has a credibility problem. The underlying issues are multi-factorial such as inadequate training in rigorous research methods, irreproducibility of results, logical fallacies and statistical mistakes during data analysis and interpretation, erroneous communication, sloppy literature outputs, and outright misconduct (e.g., [1–6]). The result is an ongoing pandemic of retractions [7–10]. That in turn can undermine public confidence in research outcomes and transparent policy [11–13], along with societal factors such as geography or culture [14]. It is of utmost importance to properly train the next generation of scientists and protect the integrity of the central principles of scientific inquiry and discovery.

This commentary discusses the role of institutional graduate programs in promoting good research practice through teaching the core values of reliable science, while at the same time, focusing on a framework for embracing responsible scientific communication.

Main text
The role of institutional graduate education programs in promoting research integrity
There have been numerous calls to reform biomedical and health science education at the graduate level [15–17]. Yet frequently, established programs fail at conveying skill training in fundamental key competencies that are crucial to preparing graduates for the complexities of present-day workplaces: critical, interdisciplinary, and creative thinking [18]. At the R3 Center for Innovation in Science Education (R3ISE) at the Johns Hopkins Bloomberg School of Public Health (BSPH), we develop interdisciplinary graduate- and post-graduate level...
programs and resources that emphasize precisely these competencies by taking a unique approach to scientific competency training. In the United States and through a growing international network of partner institutions, we spearheaded reform efforts to educate future practitioners across the science and health disciplines in applying the philosophical foundations of science to their research; engaging in interdisciplinary collaboration; communicating effectively; and committing to the highest standards of scientific integrity. Program participants are trained in the epistemology of reliable evidence generation; applied logic; practical ethics; robust methodological approaches; and effective communication, all based on the three “R” norms of good science – Responsibility, Rigor, and Reproducibility (R³) [18].

Enhancing research integrity through responsible communication

In present times, rapidly evolving scientific evidence, mixed messaging, and sometimes misinformation, can influence the public’s fluctuating trust in science and its products [19–21]. Trust needs to be rebuilt where it was lost [22, 23], and maintained where it began to grow [24] to help increase acceptance of and adherence to public health guidelines [25, 26]. Strictly rigorous and reproducible research practices are herewith a sine qua non, but the appropriate and truthful communication of science, its methods, results and pitfalls, is just as important for enhancing research credibility. It is a scientist’s duty to devote appropriate efforts toward good science communication. Known mistakes in this field—common among amateur and professional science communicators alike—are incomplete background research, hasty assumptions, factual misrepresentations, or overstatements in social media outlets, newspapers, or interviews. In a societal climate where a considerable portion of news consumers in all parts of society is inclined to listen more to rumors and unsubstantiated claims rather than rigorous scientific evidence, a lack of responsible science communication opens the floodgates for the plagues of mis- and dis-information even wider [27, 28]. The current times are thus a continuous existential reminder of our duty to provide the public with clear and actionable information.

Appropriate science communication can and needs to adhere to good practice standards. While we concur that scientific communication is not evaluated with the same metrics as the appropriate conduct of science itself [29], we agree with those members of the science community who call for high quality standards in scientific communication [30–33]. Many current coaching efforts to help scientists become better communicators focus on doubtlessly important stylistic and strategic questions, e.g., goal setting, audience orientation, argumentation structure, choice of language, and persuasive messaging [34]. More comprehensive perspectives are needed in tandem with the growing appreciation for the roles of training in developing competences for science communication [35–37]. Furthermore, we claim that there is more to it, namely a fundamental, ethical habit of mind: Responsibility.

The notion of responsibility in the context of science communication

Communicating science responsibly implies that scientists must deliver more than jargon. If we view non-scientists as empty buckets to be impressed by and filled with sophisticated information, akin to the well-known deficit model of communication with a one-way flow of information from experts to laypersons [38], we will rightfully be perceived as arrogant and create alienation rather than alliances. There has been much debate around the deficit model [39], which initiated a push to incorporate dialogue, context, and public engagement in scientific communication [40, 41]. Members of the public are essential in scientists’ efforts to disseminate truthful information. It is important for scientists to actively reach out to the public, instead of merely talking to other specialists [42]. The words of the late Stephen Hawking come to mind, who stated that “Not only is it important to ask questions and find the answers; as a scientist I felt obligated to communicate with the world while we were learning.” Hawking’s wisdom reminds us that researchers need more confidence to explain that science is not a simple, clear-cut issue. Scientific facts are not easy to convey. They are subject to an ever-evolving process that includes constant learning, critical evaluation of new evidence, and revision of existing views and theories. The pitfalls of science such as reproducibility problems, sloppy literature, at times dubious review processes, and a rising number of retracted articles can pose a true challenge to bringing the actual nature of science across: namely the quest for truth, while maintaining the highest standards of integrity. The consequences are—not rarely—citizens who distrust the scientific process and its practitioners.

These expectations may seem understandably daunting. Most scientists have never received a formal education in this domain. Without a guiding framework that helps master challenging situations, many scientists may avoid commenting on the ambiguities that are inherent to the scientific process [43]. They might react helplessly when consulted to contradict misinformation or become defensive when asked to comment on cases of sloppy science or even misconduct. Such insecurities, however, give way to conspiracy theorists and spreaders of intentional falsehoods. They can spawn denial, at times even hostility, among many members of society.
who feel uneasy with the reality that evidence generation in science is not perfect. As scientists, we must learn to confidently explain—and not apologetically defend—that science is a dynamic process involving trial and error that does not allow quick yes-or-no answers [44].

There is no time to lose. Too long have we scientists been sitting comfortably in our academic ivory towers, hoping that some talented science writer will do the communications job with the “world out there” for us. It really is upon us to improve and prevent the spread of misinformation and misconceptions, an issue that is extremely relevant amidst the current pandemic [45].

In what follows, we outline some general, value-based guidelines (Fig. 1) built on established ethical principles [46–48] widely accepted in the scientific community that helped us, our students, and colleagues at the BSPH R³ Graduate Science Program [18, 49] in our science communications training and practice efforts. We appreciate the parallels between this and the important Responsible Research and Innovation policy framework set forth by the European Commission, to tackle societal challenges through an engagement of public and responsible actors in science and innovation [50, 51]. Similarly, our program puts a strong focus on the ethical underpinnings of scientific conduct of which responsible communication is an integral part. We are not claiming that our approach is the ne plus ultra. Rather, it is meant as a starting point to build upon, since communication is a lifelong learning process.

**Objectivity**

In science and science communication alike, “certain kinds of motivation, position, material interests, field of speciality, prominence, or other factors should not influence a researcher’s actions” and decision making [46]. This includes conflicts of interest, implicit and explicit biases, and unintentional yet still questionable research and communication practices [48, 52] to which every human being can fall victim. A responsible science communicator should be aware of those risks. Recognizing the need for constant self-improvement, scientists should do their best to develop a habit of critical self-reflection, good listening, and actively seeking feedback from peers and the public.

**Honesty**

Needless to say, intellectual honesty is at the center of doing good science—and so is honest science communication. Science practitioners have a role model function in society and must live up to it. Honesty implies truthfulness and epistemic humility, i.e., staying true to the facts that are known; realizing the limits of one’s expertise by avoiding overstatements; and recognizing gaps and ambiguities in the knowledge base. For instance, honest communication and not withholding conflicting information about vaccines can increase trust in science [53]. Acknowledgement of findings that do not fit with one’s original hypothesis can mean good things, i.e., steps to a new understanding, and can be communicated accordingly. Following wise advice attributed to Confucius, committing a mistake without correction is like committing another mistake.

**Openness**

Responsible science communication describes facts and realities, not what we desire to see or what sounds opportune. In an era of Open Science [54], scientists ought to be as transparent as possible with regard to providing open access to all current data, the methods used to obtain the data, as well as valid conclusions given the evidence available at the time [55]. This pandemic clearly demonstrates the urgent need for increasing scientific cooperation through universal access to scientific progress, which has the power to unite nations [56]. Practicing openness in science communication also includes revealing potentially confusing data or mistakes, as trial and error is an integral part of the scientific process.

**Accountability**

Closely related to the value of openness is the notion of accountability. It implies that researchers have an obligation to explain their work and justify their methods,
results, and interpretations [46]. Rigorous conduct of science is of course essential, albeit not enough for accountability to the public. There are a variety of ways by which science professionals can hold themselves accountable to broad audiences. Many journals, grant agencies or conference organizers already request abstracts in lay-terms. Upon publishing preprints, authors could provide non-technical narratives of their findings through virtual open houses, websites, podcasts, community-science forums, OpEds, social media updates or press releases. While unfamiliar at first, those communications formats can provide invaluable opportunities to interact with the sovereign that should not be missed and henceforth enhances research integrity.

Fairness

The notion of fairness includes “[…] impartial treatment [and the] lack of favoritism toward one side or another” [57]. To live up to this standard, we need to put value on clear, accessible language that does not discriminate and allows equal opportunities for participation; chooses dialogue over dominance; shows respect and mindfulness in our choice of words; demonstrates appreciative audience orientation and receptiveness to questions; and accepts critique and welcomes others’ viewpoints made in good faith.

Stewardship

Good stewardship in the context of science communication implies that we humbly understand our capacities as scientists as a privilege that is made possible for us by members of the public in the expectation that we make the best use of resources we are given. We are paid for thinking and pursuing interesting questions. Those who fund us, namely the taxpayers, should receive something back outside of research results. Scientists are serving the common good and thus should view intelligible communication as an integral part of their job, their training efforts, as well as their own, continuing education.

Outlook

There is great power in the ethical core values of good research practice, and we advocate for using them as the basis for our communication efforts as well. Certainly, persuasiveness in expression, careful choice of wording, in combination with effective messaging are integral parts of good communications crafts (wo)manship. Yet, eloquence and elegance in one’s rhetoric cannot replace a critically-thinking, ethics-oriented mindset. Responsibility toward the trust that the public puts in us should be the compass in a scientist’s fight against miscommunication, misinterpretation, misstatements, falsehoods, and pseudoscience. We owe it to society. Echoing the words of Atul Gawande [58], when “you become part of the scientific community, arguably the most powerful collective enterprise in human history, […] you also inherit a role in explaining [the nature of science] and helping it reclaim territory of trust at a time when that territory has been shrinking.”

Abbreviations

BSPH: The Johns Hopkins Bloomberg School of Public Health; R3: Rigor, Responsibility, and Reproducibility; R3ISE: R3 Center for Innovation in Science Education.

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References

1. Ioannidis JPA. Why most published research findings are false. PLoS Med. 2005;2(8):e124.
2. Fang FC, Steen RG, Casadevall A. Misconduct accounts for the majority of retracted scientific publications. Proc Natl Acad Sci USA. 2012;109(42):17028–33.
3. Casadevall A, Fang FC. Rigorous science: a how-to guide. mBio. 2016;7(6):e01902–16.
4. Casadevall A, Ellis LM, Davies EW, McFall-Ngai M, Fang FC. A framework for improving the quality of research in the biological sciences. mBio. 2016;7(4):e01256-16.
5. Flier JS. Irreproducibility of published bioscience research: diagnosis, pathogenesis and therapy. Mol Metab. 2016;6(1):2–9.
6. National Academies of Sciences, Engineering, and Medicine. Reproducibility and replicability in Science. Washington (DC): National Academies Press (US); 2019.
7. Fang FC, Casadevall A. Retracted science and the retraction index. Infect Immun. 2011;79(10):3855–9.
8. Yeoh T-T, Tan BL. An alarming retraction rate for scientific publications on Coronavirus Disease 2019 (COVID-19). Account Res. 2020;28(1):47–53.

9. Abritis A, Marcus A, Oransky I. An "alarming" and "exceptionally high" rate of COVID-19 retractions. Account Res. 2020;28(1):58–9.

10. Greensaluk CK, Marcus AR, Oransky I. Institutional research misconduct reports need more credibility. JAMA. 2018;319(13):1315–6.

11. National Research Council (US) and Institute of Medicine (US) Committee on Assessing Integrity in Research Environments. Integrity in scientific research: creating an environment that promotes responsible conduct. Washington (DC): National Academies Press (US); 2002.

12. Daviey M. Retracted studies may have damaged public trust in science, top researchers fear. The Guardian. 2020.

13. Moodie G. Fudged research results erode people’s trust in experts. The New York Times. 2020.

14. Scarrfuto J. Do you trust science? These five factors play a big role. Science. 2020.

15. Lorsch J, Gammie A, Singh S. Catalyzing the modernization of graduate education. Microbe Magazine. 2016;11:96–7.

16. Leshner Al. Rethinking graduate education. Science. May 15, 2015;349(6246):349.

17. Yamamoto K, Bassler BL, Cech T, Charo RA, Fishman M, Horvitz HR, Hyman S, Landis S, Marrack P, Tilghman S, Varmus HE, and Zerhouni E. A vision and pathway for the NIH. 2016; National Institutes of Health, Bethesda, MD.

18. Bosch G, Casadevall A. Graduate biomedical science education needs a new philosophy. mBio. 2017;8(6):e01539-17.

19. Kennedy B, Tyson A, Funk C. Americans’ Trust in Scientists, Other Groups Declines. Pew Research Center. 2022.

20. Rabeasandrationa T. France is wary of science and vaccines, global survey finds. Science. 2019;366(6446):1122.

21. Bromme R, Mede NG, Kremer B, Ziegler R. An anchor in troubled times: trust in science before and within the COVID-19 pandemic. PLoS ONE. 2022;17(2):e0262823.

22. Parkish S. Why We Must Rebuild Trust in Science. Trend. 2021. p.8–12.

23. Ducharme J, Park A. Biden’s Real COVID-19 Challenge Is Restoring a Nation’s Trust in Science. TIME. 2020.

24. Welcome Global Monitor. How Covid-19 affected people’s lives and their views about science. Wellcome. 2021.

25. Sulik J, Deroy O, Deizacche G, Newson M, Zhao Y, El Zein M, et al. Facing the pandemic with trust in science. Humait Soc Sci Commun. 2021;8(1):301.

26. Sturpis P, Brunton-Smith I, Jackson J. Trust in science, social consensus and vaccine confidence. Nat Hum Behav. 2021;5(11):1528–34.

27. Vicario MD, Bessi A, Zollo F, Petroni F, Scala A, Caldarelli G, et al. The spreading of misinformation online. Proc Natl Acad Sci USA. 2021;118(29): e2024597118.

28. West JD, Bergstrom CT. Misinformation in and about science. Proc Natl Acad Sci USA. 2021;118(15): e1912441117.

29. Hilgartner S. The dominant view of popularization: conceptual problems. Political Uses Soc Sci Stud. 1990;20(3):159–39.

30. National Communication Association. NCA Credo for Ethical Communication. 1999.

31. Dietz T. Bringing values and deliberation to science communication. Proc Natl Acad Sci USA. 2013;110(3):14081–7.

32. Medveczky F, Leach J. The ethics of science communication. JCOM. 2017;16(4):E.

33. Priest S, Goodwin J, Dahlstrom MF. Ethics and practice in science communication. Chicago, IL: The University of Chicago Press; 2018.

34. Alan Alda Center for Communicating Science. The Alda Method: Story Brook University 2014. Retrieved 22 Sept 2021 from https://www.aldacenter.org/aldamethod.

35. Fähnrich B, Wilkinson C, Wettkamp E, Heintz L, Ridgway A, Milani E. RETHINKING science communication education and training: towards a competence model for science communication. Front Commun. 2021. 6.

36. Dudo A, Besley JC, Yuan S. Science communication training in North America: preparing whom to do what with what effect? Sci Commun. 2021;43(1):53–63.

37. Besley JC, Dudo A, Storksdieck M. Scientists’ views about communication training. J Res Sci Teach. 2015;52(2):199–220.

38. Davies SR. Constructing Communication: talking to scientists about talking to the Public. Sci Commun. 2008;29(4):413–34.

39. Cortassa C. In science communication, why does the idea of a public deficit always return? The eternal recurrence of the public deficit. Public Underst Sci. 2016;25(4):447–59.

40. Seethaler S, Evans JH, Gere C, Rajagopalan RM. Science, values, and science communication: competencies for pushing beyond the deficit model. Sci Commun. 2019;41(3):378–88.

41. Riecke CM, Bredenoord AL, van Mil MH. From deficit to dialogue in science communication: The dialogue communication model requires additional roles from scientists. EMBO Rep. 2020;21(9):e51278.

42. Rees M. How can scientists best address the problems of today and the future. Aeon. 2020.

43. Turkla L. Scientists are failing miserably to communicate with the public about the coronavirus, Boston Globe. 2020. Retrieved 3 Nov 2021 from https://www.bostonglobe.com/2020/07/27/opinion/scientists-are-failingly-misleadingly-communicate-with-public-about-coronavirus/.

44. Hiltsik M. Column: How a retracted research paper contaminated global coronavirus research, Los Angeles Times. 2020. Retrieved 12 Nov 2021 from https://www.latimes.com/business/story/2020-06-08/coronavirus-retracted-paper.

45. Fleming N. Coronavirus misinformation, and how scientists can help to fight it. Nature. 2020;583(7814):155–6.

46. National Academies of Sciences, Engineering, and Medicine. Fostering Integrity in Research. Washington DC: The National Academies Press; 2017.

47. National Academies of Sciences, Engineering, and Medicine. Enhancing scientific reproducibility in biomedical research through transparent reporting. Proceedings of a workshop. Washington DC: The National Academies Press; 2020.

48. National Academies of Sciences, Engineering, and Medicine. Responsible science: ensuring the integrity of the research process. Washington DC: The National Academies Press; 1992.

49. Bosch G. Train PhD students to be thinkers not just specialists. Nature. 2015;526(7572):182–5.

50. Petersen MB, Bor A, Jørgensen F, Lindholt MF. Transparent communication about negative features of COVID-19 vaccines decreases acceptance but increases trust. Proc Natl Acad Sci USA. 2021;118(29): e2024597118.

51. RRI Community. 2020. Retrieved 5 April 2022 from https://rri-tools.eu/.

52. Nuzzo R. How scientists fool themselves—and how they can stop. Nature. 2015;526(7572):182–5.

53. Petersen MB, Bor A, Jørgensen F, Lindholt MF. Transparent communication about negative features of COVID-19 vaccines decreases acceptance but increases trust. Proc Natl Acad Sci USA. 2021;118(29): e2024597118.

54. United Nations Educational, Scientific, and Cultural Organization. Open Science Movement. Retrieved 16 Nov 2021 from http://www.unesco.org/new/en/science-and-information-portals-and-platforms/goap/open-science-movement/.

55. Health TLD. Transparency during global health emergencies. Lancet Digit Health. 2020;2(9): e441.

56. UNESCO. UNESCO, WHO and the UN High Commissioner for Human Rights call for “open science”, UNESCO.org. 2020. Retrieved 17 Oct 2021 from https://en.unesco.org/news/unesco-who-and-high-commissioner-human-rights-call-open-science.

57. Merriam-Webster. (n.d.). Fairness. In Merriam-Webster.com dictionary. Retrieved 22 Feb 2021 from https://www.merriam-webster.com/dictionary/fairness.

58. Gawande A. The mistrust of science, The New Yorker 2016. Retrieved 8 Sept 2021 from https://www.newyorker.com/news/news-desk/the-mistrust-of-science.

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