FEATURE ARTICLE

Combatting Misinformation through Science Communication Training

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Abstract

As the dual crises of the ongoing COVID-19 pandemic and worsening climate change show, the public must be accurately informed about science. However, many barriers hinder effective messaging about science to the public, including little formal communication training for scientists and an abundance of misleading information from nonscientific sources. Being able to communicate with the public is a vital skill that should be a formal component of scientific training. Here, we synthesize the rationale for incorporating public science communication into undergraduate biology programs and provide specific examples of curriculum efforts to improve undergraduates' skills in this area. We review the literature about the importance of communicating scientific concepts to the public and previous efforts to integrate communication into biology curricula. Next, we provide examples of two courses aimed at developing public science communication skills and describe their integration into an undergraduate biology curriculum. We conclude with future directions and recommendations.

Key Words: *science communication/sci-comm; undergraduate; curriculum; student choice; misinformation.*

○ Introduction: The Critical Need for Effective Science Communication to the Public

Since COVID-19 emerged in early 2020, inaccurate, misleading information has helped catalyze the worldwide pandemic. Misinformation has led to vaccine hesitancy, dismissal of public health measures (e.g., mask wearing), and adoption of unproven treatments. In fact, the World Health Organization (WHO) has listed vaccine hesitancy as one of the top 10 threats to global health (WHO, 2019). Americans who are not vaccinated against COVID-19 are 10–11 times more likely to die from COVID than their vaccinated counterparts (Centers for Disease Control and Prevention [CDC], n.d.). Despite this, over 30% of Americans ages 12 and up are not fully vaccinated against the disease (CDC, n.d.). Globally, misinformation is fueling vaccine hesitancy. A recent survey indicated that more than 1 in 10 respondents used social media for health information; almost 9% used social media to evaluate treatment options (Hannon, n.d.). A 2020 report found that networks on social media platforms like Facebook are leading contributors to vaccine hesitancy because they allow the fast spread of rumors and myths regarding vaccination (European Centre for Disease Prevention and Control, 2020).

We describe the learning outcomes, major assignments, and student feedback of both courses as examples of how instruction in public science communication can be infused into science curricula.

Healthcare providers' communication skills may also contribute to public distrust. Hospital funding is linked to patient responses to the Hospital Consumer Assessment of Healthcare Providers and Systems survey (2021), which asks eight questions related to communication (e.g., how often did your doctors explain things in a way that you could understand?). Accreditation standards support patients' rights to effective patient-provider communication, but patient communication needs are often unmet. In fact, ineffective patient-provider communication is cited as a significant factor contributing to adverse health outcomes (reviewed in Patak et al., 2009).

The importance of science communication is not restricted to the healthcare domain. For at least a decade, scientists have advocated for improvements in how climate change researchers convey their findings to the public (Summerville & Hassol, 2011). Although evidence for human-induced global warming grows more compelling each year, a trend capped by a troubling 2021 report from the Intergovernmental Panel on Climate Change (IPCC), the public continues to be underinformed about its dangers (Corner et al., 2018). In the 2020 Yale Climate Change

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Opinion survey, nearly 30% of Americans surveyed thought that climate change would not harm future generations (Yale Program on Science Change Communication, 2020). The topic can seem abstract or distant from many people's day-to-day experiences. For example, 58% of respondents to the Yale survey believe that climate change will not affect them personally. In addition to these challenges, misinformation campaigns by vested-interest groups have contributed to polarization and limited understanding of the issue (Corner et al., 2018; van der Linden et al., 2017). Successful communication of complex scientific ideas to the lay public is essential to combat misinformation and support health and safety initiatives.

○ Science Communication Policy & Education

Science communication (sci-comm) is the practice of informing, educating, and raising awareness of science topics to nonspecialist audiences through written and oral mediums (Burns et al., 2003). In a 2017 report, the National Academies of Sciences, Engineering, and Medicine (NASEM) identified the five general goals for science communication as sharing recent findings and excitement for science; increasing public appreciation of science; increasing knowledge and understanding of science; influencing the opinions, policy preferences, or behaviors of people; and ensuring that a diversity of perspectives about science are considered when solutions to societal problems are pursued (NASEM, 2017).

Science communication scholars suggest that misinformation is rooted in education, political and religious affiliation, and a troubled history with the scientific establishment. The Tuskegee experiments, for example, exacerbated mistrust from African American communities (Freimuth et al., 2001, as cited in NASEM, 2017). The authors of the NASEM report link knowledge gaps in science education with ineffective communication based on unequal access to resources. Scientists must reach out to resistant audiences who may be skeptical due to less education, membership in marginalized groups, ideological beliefs, or a historically negative relationship with science (NASEM, 2017). In response to the NASEM's call, scholars have proposed strategies to improve public attitudes toward science. For example, Kappel and Holmen (2019), Orthia and colleagues (2021), and others believe that incorporating local knowledge (e.g., expertise about local flora and fauna) into research, encouraging public collaborations with scientists to collect and analyze data in citizen science projects, and fostering public participation in policy discussions (e.g., about research funding) can bridge the gap between researchers and laypeople, enhancing scientists' credibility. Social scientists Scheufele and Kraus describe "motivated information processing" in which audiences reject reproducible evidence that doesn't corroborate their worldview (2019). The authors link this response to decreasing science coverage in the news cycle. Like Scheufele and Kraus, Brownell et al. (2013a) point to problems with mainstream science information sources such as the shrinking presence of science journalism. Because of the issue's complexity, these problems must be addressed on multiple fronts. Multiple researchers posit undergraduate and graduate education as part of a multipronged solution to the misinformation problem (Brownell et al., 2013a; Kappel & Holmen, 2019; Orthia et al., 2021).

○ Enhancing Sci-Comm Skills in Undergraduate Biology Programs

Scientists must learn to successfully assess different audiences and present complex information to them in accessible, targeted ways. Science communication training must start early—in undergraduate STEM programs. Sci-comm skills are especially important for biology undergraduate students, many of whom plan to pursue healthcare careers.

The 2011 Vision and Change in Undergraduate Biology Education (V&C) movement underscored this issue's importance. Spearheaded by the American Association for the Advancement of Science (AAAS), V&C developed a shared vision for biology education (AAAS, 2011). According to the report, effective communication should be a core competency for all biology students as a basic requirement for participating in inclusive and diverse scientific communities. The report advocated for practicing science communication through formal and informal written, visual, and oral methods as a standard part of undergraduate biology education. Other initiatives, such as the Scientific Foundations for Future Physicians (Association of American Medical Colleges & Howard Hughes Medical Institute, 2009) and BIO2010 (National Research Council, 2003) also emphasize the importance of communication skills for undergraduate biology students. These calls have been echoed in biology education literature. For example, Brownell and colleagues (2013a) made a cogent argument for "incorporating formal communication training into undergraduate and graduate curricula for aspiring scientists."

To address the needs highlighted by AAAS and others, undergraduate biology curricular initiatives that fit into the broader educational movement Writing Across the Curriculum (WAC) have been implemented. First conceived over four decades ago, WAC is a nationwide reform designed to engage students with writing in their disciplines, not just in English courses. WAC initiatives incorporate specific instruction in composition (learning to write) and using writing as a mode of learning and constructing knowledge (writing to learn) (McLeod & Soven, 1992).

Learning to write initiatives within the undergraduate biology context have shown promise. When biology instructors integrated scientific communication alongside teaching of scientific concepts, they found that student confidence in communicating science increased (Brownell et al., 2013b). After a science communication module was integrated into an introductory biology lab, students were able to apply essential elements of scientific communication (Wack et al., 2021). In a qualitative study, instructor strategies promoted increased use of effective scientific communication skills in an undergraduate environmental science course (Shivni et al., 2021). These studies demonstrate that explicit instruction improves undergraduates' science communication skills.

A growing body of literature suggests that writing to learn enhances undergraduate students' understanding of biological concepts. Mercer-Mapstone and Kuchel (2016) found that students learned subject-specific science content through the communication activities. Balgopal and colleagues (2018) found that writing activities in a cell biology course led to performance gains in summative exams. Other research also shows that assignments involving communication led to gains in quantitative reasoning, interpretation of scientific results, and conceptual learning of core science content (e.g., Kuchel et al., 2014; Schroeder & Greenbowe, 2008; Moni et al., 2007). As a form of problem-solving and critical thinking, writing can complement other ways to learn science.

○ Integrating Sci-Comm Training into Biology Curricula: An Example from the University of Kentucky

Sci-comm initiatives can be embedded within a course and/or integrated as part of a larger curricular design. Here, we describe an undergraduate biology curriculum reform effort aimed at developing students' science communication skills. The revised curriculum incorporated both learn to write, write to learn, and oral communication skill development.

The University of Kentucky, a public land grant institution, serves as Kentucky's flagship university. In 2014, the university implemented a Graduation Composition and Communication Requirement (GCCR), which was designed to extend education in multimodal composition and communication. The GCCR model carried the emphasis on composition and communication from the lower-level writing courses into the upper levels of individual majors and programs. Courses that fulfill the GCCR must include at least 4500 words of formal writing and allow students to revise their writing after instructor feedback. To satisfy the requirement, students must also complete two oral presentations, with instructor feedback after the first presentation incorporated into the second presentation. Programs may choose to have students complete both the written and oral presentations within one course or split the requirements between courses.

Biology is one of the largest undergraduate majors at the University of Kentucky, with almost 1400 students. When the GCCR was first introduced, the biology program used one laboratory course to fulfill the requirement's written portion. Two major issues arose from having over 300 students per year fulfilling the GCCR requirement in a single course. First, the amount of writing required, combined with the feedback requirement, burdened teaching assistants. In addition to the time necessary for grading, graduate students required extra training to maximize their feedback and evaluation skills. Second, the fact that all students wrote about the same laboratory experiment meant that they could not write about their specific interests, decreasing motivation and increasing instances of plagiarism.

In 2019, the biology department revised the curriculum to allow students to meet the written requirement of the GCCR through one of nine course options. The curriculum choices were intended to help students be adept when communicating with different audiences in diverse situations. Six of the options are upper-level biology electives taught by biology faculty. In these courses, discipline-specific writing conventions are taught concurrently with scientific concepts; students use writing assignments to solidify their understanding of course concepts (writing to learn). Two of the course options (Writing Public Science and Writing in the Natural Sciences) are taught by Writing, Rhetoric, and Digital Studies department faculty. These courses (one described in detail below) focus on the development of scientific writing skills (learning to write). The final option allows students participating in independent research to fulfill the requirement by writing about their project, usually in the form of a formal scientific report. This flexible suite of options better serves our diverse student's needs, allowing them to tailor their educational experience to specific interests/goals. Since the new GCCR options have small class sizes, faculty experts assess student writing and provide robust feedback.

In biology, the GCCR oral communication component is fulfilled through a senior seminar course. Multiple sections of the course are offered (one described in detail below), each focused on a relevant topic in modern biology. In each section, students complete two oral presentations, usually in a journal-club style. Like the revised options for the written requirement, the senior seminar's advantages include students' ability to tailor the experience to their interests, small class sizes, and expert faculty feedback.

○ Infusing Public Science Communication into Biology Courses

Two courses within this revised curriculum—Writing Public Science and one section of the Biology Senior Seminar—were specifically designed to provide training in sci-comm. Here, we describe the learning outcomes, major assignments, and student feedback of both courses as examples of how instruction in public science communication can be infused into science curricula.

Writing Public Science

Writing Public Science, taught by K. Rogers-Carpenter, is an upper-level writing course created for students interested in making complex scientific ideas accessible and exciting to general audiences. Although participants are typically junior- or senior-level biology majors, nursing, clinical leadership, and rhetoric majors also enroll in the class. Through a combination of formal essays and informal exercises, students write 5000–6000 words during the semester. Major assignments include a research proposal, a rhetorical analysis, an op-ed, and a final mini-article. In addition to instructor feedback on rough drafts and graded essays, class members review each other's work. The primary focus is on identifying target audiences and crafting texts for them.

Students first select a science-based research topic that will form the basis for every major essay and presentation that follows. They often focus on subjects from other courses such as nutrition or gene editing. But students are just as likely to research deeply personal issues like addiction or COVID-inspired anxiety. Although assignment descriptions, rubrics, and examples provide formal guidance, students determine the target audiences and publication venues for their essays. To demonstrate science communication's value and practicality, science writers are invited to talk with these students. Professional writers, science journalists, academics, and public advocates have visited the class and explained how they approach specific audiences. Interacting with these speakers helps students learn how to communicate with science writers and imagine being science writers themselves.

The second major assignment, a rhetorical analysis of a popular text, helps students understand how their topic is represented in mainstream venues. For this assignment, students analyze documentaries, popular science magazine articles, blogs, or podcasts. Along with examining the writer's rhetorical strategies and purpose, students evaluate text structure, publication venue, and target audience. Understanding these compositional features scaffolds the next major essay—an op-ed. Based on a research study about their topic, students compose an op-ed for a specific lay audience. Along with synthesizing information, they decide what the audience needs to know, what readers should think or do after reading the op-ed, and which venue appeals to these readers.

The final project, a two- to three-page publication analysis and a seven- to nine-page mini-article, helps students consider secondary and tertiary audiences and practical aspects of publishing. First, students analyze a potential publication outlet for their mini-article. To learn about the publication's target audience, they evaluate content, use of images, article length, and reader comments. They also review circulation numbers, funding, editorial priorities, and manuscript submission requirements. They compose a mini-article following these guidelines. Memorable projects include resources for families of addicted people, an extended op-ed about Kentucky's water infrastructure, and an article about Eastern Kentucky's cancer rates.

Student feedback indicated that they appreciated the autonomy of the course and that the course structure increased their motivation: "I think allowing students to pick how they want to go about their research and what they want to do is really important." Another student commented that "[the course structure] made me want to do more, and it made me want to participate."

Biology Senior Seminar

A senior seminar for biology majors taught by J. Osterhage provides another example of a course that incorporates communication skills for a lay audience. Subtitled "Epigenetics and the Environment," the seminar's goal is to survey primary and popular literature on the effects of environmental factors on epigenetic gene regulation. The course enrolls 14 students each semester, most of whom are interested in pursuing healthcare careers after graduation.

Multiple course activities are scaffolded to help students develop communication skills to a lay audience. First, students are provided with a published primary research study and an accompanying public science article and asked to compare how science is communicated to other scientists (via primary literature) with how the same study is communicated to the public. During class, students discuss how effectively the public science article conveys the research article's results. We explicitly examine whether the public science article includes misinformation, including misleading claims about the study's results. Two of the public science articles were chosen specifically because they include dubious conclusions about the primary literature article's results. Students are often surprised that such bold claims are made in the layperson piece.

The first five minutes of the 15-minute oral presentations are dedicated to an introduction to the topic geared toward a nonscientific audience, and the remaining time is used to present a primary research article of the students' choosing. Students are separated into small groups (three or four students) for their first presentation, which is recorded. After watching the recording, students write a brief reflection about their strengths and areas of improvement. Students are also provided with both peer and instructor feedback on the first presentation to improve the second. During the Q & A period following each presentation, students are assigned to be "patients"—to ask questions as a patient might. Students also write a public science article related to the primary literature article they choose, making sure to avoid misleading or dubious claims.

While students choose their presentation topics under the general theme of epigenetics and the environment, they typically select topics relevant to their lives or future careers. For example, a student interested in dentistry presented a paper about epigenetic changes in mouth bacteria under different conditions. Another student, who had type 1 diabetes, presented on the epigenetic connection between environmental factors and diabetes progression.

Student course evaluations indicate that they appreciate the autonomy to choose their own topic, that the first presentation in small groups alleviates anxiety, and that peer and instructor feedback help them become more effective communicators. Other comments describe how the course helped them understand the importance of communication skills: "Learning how to create an engaging presentation is essential to becoming a successful scientist. I really enjoyed how we spent time discussing the best ways to present our research."

○ Implications for Biology Programs & Instructors

We are just beginning to understand the implications of these changes to our biology curriculum and our two courses in particular. Course feedback indicates that these approaches have helped students gain sci-comm skills (learning to write and speak about science), increased their excitement about science, and aided in their understanding of scientific concepts (writing to learn)—outcomes directly aligned with the sci-comm training goals described in the NASEM report. Opportunities to practice communicating with nonscientific audiences helps prehealth students envision communication with patients as an important part of their future career. Both courses make the sciences seem more practical and practicable; students now have a chance to imagine themselves as health professionals communicating with patients or as scientists writing for and communicating with the public. Allowing students to research a topic of their interest results in increased student motivation and eagerness to learn science. Importantly, these changes were implemented relatively quickly and without additional faculty resources or funding.

Implementing communication training in our courses has been a positive experience for faculty. Instructors in these smaller courses are more engaged in helping students learn to communicate effectively, and they can use writing assignments to assess student skills and progress more holistically than conventional multiple-choice exams. The curricula's interdisciplinary nature also enriches the teaching experience. For example, in addition to modeling science communication for students, inviting guest speakers helps forge productive connections between the instructors and colleagues from other departments or the greater community. Reaching across disciplines helps writing faculty better understand their STEM students.

Significantly, instances of plagiarism in writing assignments noticeably decreased after the revised curriculum went into effect. When all students wrote the same lab report, they were often plagiarized from online sources. Now, because students are more engaged in their writing, they are less likely to plagiarize.

The assignments and activities that we have discussed here could be adapted to a variety of contexts, including high school biology classes. For example, high school biology instructors could collaborate with English instructors to develop an op-ed assignment related to a scientific issue. Blogging about an issue of interest would also develop sci-comm skills and help students learn to support their claims with credible evidence. Science educators could also consider replacing or supplementing a traditional lab report with a popular science article assignment to give students practice presenting their findings to a nonscientific audience. In addition, assigning peers to "play the patient" for the Q & A period after presentations would allow students to develop oral sci-comm skills that may be aligned with their future career goals.

○ Looking Ahead

In the future, we plan to quantitatively assess the effects of our curriculum and course changes. First, we will determine the extent to which writing and communicating about science helps our students learn biological concepts. We will also evaluate whether these changes help students more effectively distinguish between accurate and misleading information. We would like to develop avenues by which students can publish their writing in public venues. Publishing beyond the classroom, even in low-stakes venues like blogs, would extend the audience beyond just the instructor and make writing more transferable and meaningful.

A growing number of universities have developed academic minors in sci-comm (e.g., Cornell University). These training options have distinct advantages for students, including targeted training and formal recognition for sci-comm skill development. However, many institutions do not have the resources to fully invest in a new minor. Development of an undergraduate certificate in sci-comm (which usually requires fewer credit hours than a minor) is an alternative that would give students additional training opportunities and formalized recognition for their skills. We plan to design such a certificate at the University of Kentucky and include the courses described here in the certificate curriculum. This certificate would appeal to biology undergraduates entering healthcare fields, communication majors looking to develop a specific skill set, and others interested in developing their scientific communication skills.

The ultimate goal of these curricular and course reforms is to contribute to a science literate society and to combat misinformation. Providing students with stronger communication skills will help them not only develop professionally but also combat dangerous misinformation and directly address the world's most urgent problems.

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