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Better science through rhetoric: A new model and pilot program for training graduate student science writers

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ABSTRACT

Graduate programs in the sciences offer minimal support for writing, yet there is an increasing need for scientists to engage with the public and policy makers. To address this need, the authors describe an innovative, cross-disciplinary, National Science Foundation (NSF)–funded training program in rhetoric and writing for science, technology, engineering, and math (STEM) graduate students and faculty at the University of Rhode Island. The program offers a theory-driven, flexible, scalable model that could be adopted in a variety of institutional contexts.

KEYWORDS

Classroom research; curriculum design; pedagogical theory; rhetoric of science

Scholars in rhetoric and writing studies have a timely opportunity to shape the future of science communication. The National Science Foundation (NSF) and Council of Graduate Schools recently called for graduate programs in science, technology, engineering, and math (STEM) to incorporate science communication into graduate student training (Linton, 2013). However, a comprehensive approach for training STEM graduate students in science writing and communication remains elusive (Kuehne & Olden, 2015). Yet this move would have far-reaching consequences for scientists and wider communities. Through direct engagement with public stakeholders, scientists have the opportunity to foster greater public trust in the sciences (Lach, List, Steel, & Shindler, 2003; Pace et al., 2010), leading to more compelling and accessible scientific information being conveyed to a broader spectrum of society (Nisbet & Scheufele, 2009) and more effective incorporation of science into social and environmental policy making (Meyer, Frumhoff, Hamburg, & de la Rosa, 2010; Roux, Rogers, Biggs, Ashton, & Sergeant, 2006; Smith et al., 2013).

Here we describe an innovative, cross-disciplinary training program for STEM graduate students and faculty at the University of Rhode Island, funded by the NSF. Key to the program, called SciWrite@URI, is a unique emphasis on rhetoric, which, we argue, is an essential component of science communication education and has been lacking in many previous and existing programs. Emphasizing rhetoric throughout the program of study—and supporting STEM graduate faculty to adopt rhetorically informed writing pedagogy—positions students to challenge a deficit model of science communication (Gross, 1994) and advance critical public engagement with science (Gigante, 2014). SciWrite@URI builds from the idea that science communication training, informed by rhetoric and implemented from the first graduate semester, improves faculty's teaching and students' academic writing, public communication, and broader impacts, while improving students' comprehension of scientific concepts, familiarity with their disciplinary communities, and confidence as writers and scientists.

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A lack of training for graduate student science writers

Other than occasional, isolated courses in proposal and manuscript writing, STEM graduate programs have typically offered minimal support for graduate students in writing and communication (Kuehne et al., 2014), and available courses are rarely taught by faculty trained in rhetoric, writing studies, or communication. Even though it is widely acknowledged that ineffective writing can inhibit academic publication (Gopen & Swan, 1990; Moore, 1994), graduate programs in the sciences are typically oriented toward training graduate students to master their disciplinary sciences, viewing writing as an add-on outreach method for disseminating already fully articulated results. The traditional model of STEM graduate student training involves first the preparation of a brief proposal, and then completing milestones of data collection and analysis for research (Kuehne et al., 2014). When students do receive writing guidance, it may come only at the end of their academic programs, typically from informal advisor interaction rather than more structured mechanisms like coursework, and in strictly academic genres, like theses, dissertations, and articles for publication. Not all STEM students receive writing-specific training; a variety of studies point to a lack of advisor support (along with a lack of time and lack of knowledge of opportunities) as a major barrier to graduate training in communication and outreach (Andrews, Weaver, Hanley, Shamatha, & Melton, 2005; deKoven & Trumbull, 2002; Kuehne et al., 2014; Salguero-Gomez, Whiteside, Talbot, & Laurance, 2009). This overarching model, where training—if it exists at all—is delayed in students' progress to degree and limited strictly to academic genres and contexts, has consequences for research practice, for science competency in the broader public, and for STEM graduate students' future potential.

These challenges are further complicated in the case of second language (L2) learners, with English as a second language (ESL) graduate students encountering similar challenges to their first language (L1) counterparts, but also facing unique obstacles as L2 learners (Abasi, Akbari & Graves, 2006; Angelova & Riazantseva, 1999; Casanave, 1992). Like native speakers, graduate students who are non-native English speakers struggle with issues like mechanics, syntax, clarity, and concision. However, because of factors that include a diversity of cultural backgrounds and pedagogical differences in past ESL training (Dong, 1998), higher-order concerns central to writing proficiency —such as engagement in communities of practice, rhetorical expression, and the ability to write for different audiences—may present greater challenges, especially at the graduate level. Because only 3% of U.S. undergrads are ESL speakers, undergraduate writing centers are often able to fold ESL speakers into existing services (Aneja, 2014; Yoon, 2013). But ESL graduate students make up 44% of the U.S. graduate student body (Yoon, 2013) and tend to be faced with an unavailability of graduate-focused support resources. Compounding the problem is that STEM faculty advisors are not often well equipped to address the complexities associated with ESL learning.

But deep, student-centered training in writing is essential for student success academically, professionally, and publicly. For L1 and L2 learners, early training in scientific writing can contribute to students' ability to participate in their scientific disciplines (Chinn & Hilgers, 2000), can improve students' comprehension of scientific concepts (Keys, 1999; Rivard & Straw, 2000; Wallace, Hand, & Prain, 2004), and can help build students' confidence in communicating science to broader audiences. At the same time, enhancing graduate students' science communication skills prepares them for a broad spectrum of career paths. The vast majority of STEM graduates will not become research scientists, instead working with the public or in industry (Linton, 2013). In 2006, just 15% of PhD graduates in the biological sciences were in tenured positions (and 18% untenured) 6 years after graduating (Cyranoski, Gilbert, Ledford, Nayar, & Yahia, 2011). It seems likely the remainder of graduates will be in jobs with much less demand for academic science writing, though those in tenure and nontenure track positions will need a wider array of writing skills to write successful grant proposals and engage in broader impacts activities with diverse public audiences and policy makers.

Existing models of science communication training for STEM graduate students

Recent years have witnessed a rise in universities offering new workshops (e.g., Michigan State University, University of Washington) and courses (e.g., Northwestern University's Science in Society, University of Wisconsin Milwaukee, Colorado State University) aimed to address a lack of science communication training for STEM graduate students and faculty. Some national programs feature special training events (e.g., University of Rhode Island's Metcalf Institute for Marine & Environmental Reporting, the Alan Alda Center for Communicating Science at Stony Brook University, COMPASS, American Association for the Advancement of Science [AAAS], NSF's Becoming the Messenger program), and a few federal fellowships exist for longer term training in policy-related science communication (e.g., Knauss Marine Policy Fellows, AAAS Emerging Leaders in Science and Society program, United States Geological Service's Northwest Climate Center Climate Communication Fellowship; Kuehne et al., 2014, Table 2). Many of these initiatives are summarized in Kuehne et al. (2014), Table 2, with information about each program's "intended career stage," "time investment," and "science communication training and skills emphasis." What is clear from that table and from our own research is that besides the PhD specialization in life sciences communication at the University of Wisconsin–Madison and a graduate certificate in science communication at George Mason University, we know of no other comprehensive program specifically for STEM graduate students providing long-term, intensive writing support from the beginning of their coursework and targeted at diverse audiences. Crucially, we know of none that are built on a primary foundation in rhetoric and writing studies.

Much of the current focus in science communication training is on teaching students to craft simple and persuasive messages about their research. Often these efforts build from a deficit model of communication, where students are taught to transmit content to passive audiences, rather than featuring more engaged, rhetorical approaches focused on iterative communication and the coproduction of knowledge (Druschke & McGreavy, 2016; Gross, 1994). But, as one of us has argued elsewhere, "Although strategic communication is important, communicating relevant science to broad public audiences in consequential ways warrants a richer view of communication informed by rhetoric's strategic, relational, and material dimensions" (Druschke & McGreavy, 2016, p. 47). As science communication training evolves, there is significant room for it to incorporate rhetorical approaches that expand beyond the strategic to offer students relational and material or ecological approaches to communicating with academic and public audiences and to facilitate engagement with target audiences. When the funding mechanism was first announced in 2015, we were excited by the possibility the NSF's Innovations in Graduate Education track might offer to combine our backgrounds in rhetoric, writing studies, and the biological sciences to consider how best to train science students and faculty in rhetoric and what students and faculty might gain from that training. SciWrite@URI is our answer to that question.

SciWrite@URI: A rhetorical model for graduate student science writing education

To address this lack of comprehensive training and its far-reaching consequences, our interdisciplinary team at the University of Rhode Island considered ways to integrate the explosion of practical and theoretical literature in science communication with the rich history of initiatives and approaches in Writing Across the Curriculum (WAC) and Writing in the Disciplines (WID) through an overarching rhetorical framework. Where science communication offers strategic insights into the role of popular science writing, models for public engagement, and various applications for practitioners (Bucchi & Trench, 2014; Perrault, 2013; Russell, 2010), existing models rarely focus on the development of individual writers. Research in writing studies bridges this gap, specifically with its emphasis on creating habitual writers capable of responding to and through situation, audience, and genre, and on incorporating peer review and revision processes (Crowley & Hawhee, 2011; DiPardo & Freedman, 1988; Hawhee, 2002; Lundstrom & Baker, 2009). Rhetoric, meanwhile, can tie together science communication and WAC/WID perspectives, emphasizing

relational and ecological approaches to language that can contribute to scientists' evolving and consequential perspectives on language, persuasion, argument, public discourse, and civic engagement (Cooper, 1986; Druschke & McGreavy, 2016; Eberly, 1999; Simmons, 2010; Toulmin, 2003).

Our collective interest is in integrating WAC/WID, science communication, and rhetoric and writing studies with the natural sciences and food sciences. Thus, in fall 2015, we applied for and were awarded $500,000 from the NSF's Innovations in Graduate Education track of their Research Traineeship program to create a 3-year pilot STEM graduate training program in science writing and communication. The program, SciWrite@URI, which was at the end of its 2nd year at the time of this writing, builds from a unique disciplinary foundation in rhetoric and writing studies to cultivate confident and effective graduate student science writers and the faculty who support them. The goal is to improve students' science writing and their potential to effect larger professional and societal outcomes. Feedback from NSF reviewers commended the fully integrated proposed curriculum, jointly developed by faculty in the Departments of Writing & Rhetoric, Natural Resources Science, and Nutrition and Food Sciences. Reviewers recognized that the SciWrite@URI curriculum emerges from advances in writing pedagogy from the humanities and natural sciences, with all faculty engaged as full partners in program design, execution, and assessment.

SciWrite@URI offers an innovative, cross-disciplinary model of science communication grounded in three core principles: habitual writing, multiple genres, and frequent reviews. Through coursework, workshops, internships, boot camps, and a graduate science writing center, SciWrite@URI integrates diverse types of science writing and communication from the beginning of and throughout graduate students' scientific training, while also providing rhetorical training for the STEM faculty who advise students throughout their graduate school tenure. This evidence-based model cultivates knowledge and skills in writing and communication across multiple audiences over the entire course of graduate student training so that students develop authoritative scientific voices that more effectively advance their research and broader impacts.

Rather than training graduate science writers to focus only on producing academic discourse near the end of their education, SciWrite@URI emphasizes rhetorical education from the beginning of a graduate student's coursework. Graduate students are expected to engage in science writing for multiple audiences from the outset of their training. Workshops and scaffolded coursework ensure that students learn early and often how to best communicate their science through a number of genres to multiple nonspecialist and nonacademic audiences as well as to their scientific colleagues. By introducing rhetorical principles and practices from the first semester of their graduate training, this model provides valuable opportunities for graduate science writers to build more confidence about their projects from the beginning of their programs of study and to reach a wider variety of audiences with their work. The program also trains STEM faculty to better support students through that writing process.

The three-legged stool of SciWrite@URI: Habit, genre, review

Drawing from and synthesizing research and theory in genre studies as well as recent WAC research and decades of process and postprocess theories and practices of writing instruction, the SciWrite@URI training model builds from three distinct emphases: habitual writing, multiple genres, frequent reviews.

Habitual writing

In the SciWrite@URI model, graduate student science writers write early and often, and through rhythm, repetition, and response develop a regular practice or habit of writing (Hawhee, 2002). A modern version of the classical *progymnasmata* (Crowley & Hawhee, 2011) and a common feature of WAC programs, frequent, brief, and typically ungraded writings—microthemes, minute papers, freewrites, or other versions of writing to learn—offer concrete ways for graduate student writers to incorporate habitual writing into their practice while graduate faculty learn how to introduce

habitual writing and incorporate it into their graduate courses. Introduced in the first workshop and reinforced through courses, writing boot camps, and another key element of frequent reviews, habitual writing helps demystify the writing process for graduate science writers well before they enter the thesis proposal drafting stage. Three-time weekly SciWrite@URI boot camps held in two campus locations offer regularly scheduled, dedicated time and space for graduate students and faculty to focus solely on their writing projects.

The overarching goal of the boot camps is to create a sense of community to reinforce habitual writing practice in what can often feel like a very isolating activity, particularly at the dissertation level. SciWrite@URI faculty fellows periodically attend writing boot camps and direct their advisees and students to participate. The SciWrite@URI team also coaches faculty fellows to incorporate habitual writing activities into their own STEM syllabi.

Multiple genres

Graduate science writers participating in SciWrite@URI practice early and often in multiple genres (e.g., manuscripts, blog posts, news articles, editorials, procedures, field notes, White Papers, grant proposals) for actual academic and nonacademic audiences (e.g., lay readers, technicians, practitioners, journalists, and expert scientists serving on boards and committees). Practice in writing for multiple genres is introduced in courses, workshops, and internships. Teaching for genre awareness helps graduate science writers understand the communities of practice for which they write (Miller, 1984; Porter, 1986), how content and form are united (Devitt, 2004), and the variety of options writers have for exploring or presenting ideas to various audiences.

Faculty are coached on how best to incorporate assignments into their graduate courses that involve writing in multiple ways for multiple audiences. Different communities of practice (Wenger, 1999) are made explicit through attention to invention or planning; to arrangement or organization; to style, voice, or tone; and to delivery, a combination of form, genre, and presentation. Graduate science writers learn how their messages change based on the different forms they take and come to understand that they have valuable knowledge and information to convey to various audiences even before they have the final results of their research. A range of science communication tools or media can deliver content, but writers need to be thoughtful about the relationships between form, content, audience, and consequence.

The goal in SciWrite@URI is to equip students with a flexible rhetorical toolkit for responding to the variety of writing tasks they face in their careers, and that message is made explicit to SciWrite@URI students (and faculty). Rather than teaching fellows to mimic one specific genre or voice, the SciWrite@URI team offers students and faculty an array of tools for critiquing and constructing in any number of writing ecologies.

Frequent reviews

Review is a normal accompaniment to writing, and research into writing processes indicates that peer review creates better writers (DiPardo & Freedman, 1988; Lundstrom & Baker, 2009). All writers need feedback to improve, and habitual writing can be achieved, in part, by having students review each other's work. Frequent reviews allow students more opportunities for analyzing aspects of their various communities of practice, especially when supported and scaffolded throughout a program of study. For graduate students in the sciences, peer review offers the additional benefit of preparing them for the rigorous review process they will face when submitting articles for publication.

SciWrite@URI graduate science writers plan and draft their writing and then enter a process of review and revision in one-on-one and small group tutorials in classrooms, online forums, and a graduate science writing center that opened in fall 2017. Interacting with reviewers (and writing consultants) gives science writers good practice in revising their writing, creating habitual practices of writing, and shaping their messages for a variety of audiences (Blakeslee, 2001). The peer review experiences that students participate in through their SciWrite@URI courses and workshops are further reinforced by the

SciWrite@URI team's work with faculty fellows. SciWrite@URI faculty fellows learn to incorporate peer review into their STEM courses, so that students engage in peer review not just in their writing- and rhetoric-focused courses, but also in their STEM coursework and with their lab mates.

Most course or learning management systems have a function for facilitating online peer review, and other stand-alone programs focus only on that feature: for example, Eli Review™ (http://elireview.com/) and My Reviewers (http://myreviewers.com/), both created by writing and rhetoric specialists. SciWrite@URI makes extensive use of Eli Review, following the lead of the writing department on our university campus. Designed to facilitate learning through multiple cycles of review and revision, Eli Review provides a platform for SciWrite@URI to provide writers with real readers and to increase expectations for multiple drafts, purposeful revision, and careful editing. Peer review, practiced through an electronic exchange of drafts or face-to-face discussion, reinforces program expectations that students learn to be attentive to audience, context, and criteria for a particular writing task. Although SciWrite@URI has benefited from Eli Review's capacity for offering peer reviews in class or out, with other SciWrite@URI students or with lab members on campus or off, online review is not essential to transferring the SciWrite@URI structure out to other schools, though, we suggest, peer review itself certainly is.

Habitual writing, multiple genres, and frequent reviews reflect best practices in the teaching of writing and form the foundation of SciWrite@URI. All three elements are critical to the goals for graduate student and faculty participants, but as the goals themselves differ, we have developed complementary but distinct activities throughout the program curriculum.

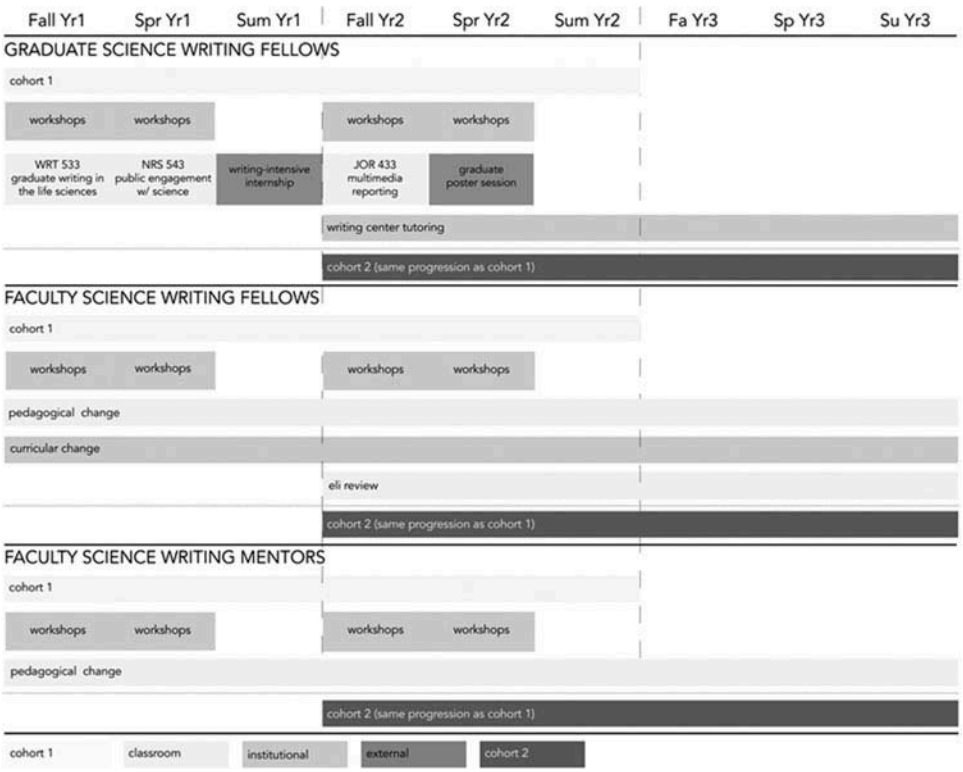

Figure 1. Progression through courses, workshop, internships, pedagogical change, curricular change, and a Graduate Science Writing Center for Graduate Science Writing Fellows, Faculty Science Writing Fellows, and Faculty Science Writing Mentors.

SciWrite@URI fellows and mentors

SciWrite@URI layers these three tenets of habitual writing, multiple genres, and frequent reviews throughout a multipronged approach to expand existing investment in graduate science writing at the University of Rhode Island by establishing cohorts of graduate students and faculty who can then mentor additional colleagues and students. The sequence described below outlines the 2-year rotation of students and faculty over the initial 3-year NSF grant (Figure 1).

Graduate student science writing fellows

Cohorts of Graduate Student Science Writing Fellows (six students per cohort) proceed through a 2-year sequence that emphasizes habitual writing, multiple genres, and frequent reviews through coursework, workshops, internships, a poster session, boot camps, and peer tutoring in a new Graduate Science Writing Center (Figure 1). Graduate Science Writing Fellows complete three sequential, required courses that emphasize habitual writing, multiple genres, and frequent reviews: (1) Graduate Writing in the Life Sciences in the Department of Writing & Rhetoric, (2) Public Engagement with Science in the Department of Natural Resources Science, and (3) Using Multimedia to Communicate Science in the Department of Journalism. In addition to this three-course sequence, Graduate Science Writing Fellows participate in half-day workshops that address specific elements of the writing process in more depth (e.g., topic sentences, rhetorical analysis, and cover letter preparation) and reinforce existing course content or address needs not strictly met by it. In the summer after their first year, Graduate Science Writing Fellows complete writing-intensive internships with external agencies or organizations relevant to their research interests (in year one, those included the Metcalf Institute for Marine & Environmental Reporting, United States Geological Survey, and the Parkinson's Disease Foundation, among others), and present posters about their internship work at the University of Rhode Island Graduate Student Conference the following spring. During year two, Graduate Science Writing Fellows also serve as peer tutors who staff the new Graduate Science Writing Center.

Faculty science writing fellows

Cohorts of Faculty Science Writing Fellows (six faculty per cohort) also proceed through a 2-year sequence. Faculty Science Writing Fellows are accepted into the program based on a willingness to change the pedagogy and curricula of their graduate courses and the forms of their interactions with graduate advisees to incorporate habitual writing, multiple genres, and frequent reviews into graduate education. The faculty sequence emphasizes the integration into their pedagogy of habitual writing, multiple genres, frequent reviews through workshops and online peer review, curricular change, and involvement with the Graduate Science Writing Center (Figure 1). Faculty members integrate these emphases in graduate-level STEM classes, mentoring of their graduate students, and professional communication. In year one, Faculty Science Writing Fellows attend four half-day workshops on relevant topics like syllabus redesign and the draft-review-revise cycle of Eli Review. These workshops include time and guidance for faculty to make required adjustments to syllabi, assignments, activities, or sequencing and are supplemented by two-on-one syllabus development sessions with SciWrite@URI team members twice per semester.

Although the central goal of SciWrite@URI is to increase capacity in graduate science writers through intervention with graduate students and faculty, it is the Faculty Fellows who will have some of the most substantial long-term impact at the University of Rhode Island. We are excited to think that SciWrite@URI graduate students will complete their degrees and move on to their careers, where they will hopefully incorporate and train others in many of the rhetorical emphases of SciWrite@URI. We know that our Faculty Fellows have the potential to build capacity in successive cohorts of STEM graduate students at our university for decades. Their contributions are already

changing the culture of science writing and communication in the larger STEM community at the university. Supporting faculty in this challenging task is critical to the integration and success of other parts of the model we offer here.

Faculty science writing mentors

An additional tier of faculty members includes cohorts of Faculty Science Writing Mentors (10 faculty per cohort) who attend pedagogy workshops and implement these new approaches while mentoring their own graduate students (Figure 1). Faculty Science Writing Mentors include faculty who want to be involved in improving graduate science writing but are not yet able to integrate directed rhetorical training into their course load. These are faculty who may advise graduate students but who do not regularly teach graduate-level courses or graduate students or do not have time for the full commitment of the Fellows program. Incorporating this population into proposed training ensures broader participation of interested faculty and students not able to fully commit as Student or Faculty Fellows. Although not involved in explicit curricular change, Faculty Science Writing Mentors actively train graduate students with new rhetorical approaches to science writing and communication through one-on-one mentoring.

Building a rhetorical toolkit for STEM graduate students and faculty

SciWrite@URI's emphasis on habitual writing, multiple genres, and frequent reviews for STEM graduate students and faculty is built through a series of modes, including coursework and non-course components.

SciWrite@URI Faculty Fellows and Mentors attend frequent pedagogy workshops focused on issues like peer review and rhetorical analysis. Faculty Fellows also participate in conferences with SciWrite@URI team members who support Faculty Fellows through the work of revising at least one of their STEM syllabi to add or refine scaffolded writing projects. Faculty Fellows are asked to integrate writing pedagogy with small steps such as "chunking" assignments (breaking large writing projects into a series of smaller, low-stakes tasks) or regularly assigning peer workshops—with or without Eli Review—in or outside of the class. Frequent, individualized meetings between Faculty Fellows and SciWrite@URI team members allow SciWrite@URI to offer tailored coaching in addition to general workshops to ensure that Faculty Fellows are supported in implementing the rhetorical tools most appropriate to their teaching goals, personalities, approaches, and students.

Student Fellows participate in a more diverse array of activities than Faculty Fellows and Mentors. Their SciWrite@URI experience is stitched throughout their work over their first 2 years of graduate study. In terms of coursework, the three required courses in SciWrite@URI—Graduate Writing in the Life Sciences, Public Engagement with Science, and Using Multimedia to Communicate Science—are built on an explicitly rhetorical foundation, teaching students about rhetorical ecologies, genre as social action, and discourse communities rather than grammatical instruction. This training makes students more nimble, flexible, responsive, and persuasive writers and means that the training they gain in SciWrite@URI is widely transportable to the variety of civic and professional situations in which they find themselves now and will find themselves in the future.

A graduate-level science writing course in the Department of Writing & Rhetoric, Graduate Writing in the Life Sciences, serves students across the biological sciences. Capped at 15 students and consistently overenrolled, the course deliberately builds a cohort of students who progress together through four scaffolded, writing projects: a forum analysis, a critique of a piece of public science writing, a piece of public science writing, and a fellowship statement. The course begins with a series of rhetorically framed readings that cover foundational concepts (Druschke & McGreavy, 2016); the notion of science as social and rhetorical (Kuhn, 2012; Penrose & Katz, 2010); the concepts of genres, discourse communities, and ecologies (Cooper, 1986; Miller, 1984; Porter, 1986); and an introduction to rhetorical analysis as a flexible Swiss army knife (Selzer, 2004). Each project emphasizes

drafting, review, and revision, and students begin to identify how and why academic discourses differ from popular discourses. As a key aspect of the course's and program's focus on consequential writing, a requirement of the public science writing project is to actually submit the project to a public venue. Past and current students have written and submitted letters to the editor to *The Providence Journal*, opinion pieces to *STEMinist*, and public translations of scientific articles to the oceanography blog *oceanbites*, among other venues.

Offered in the Department of Natural Resources Science, the Public Engagement with Science course serves students from across the biological sciences, oceanography, and marine affairs. The course focuses on theoretical and practical aspects of public engagement with scientific research, policy, and management, with an emphasis on science communication. During the semester, students explore the University of Rhode Island's land grant mandate to share university research with the public and use university resources to explore public needs. Readings include an introduction to environmental communication and its views on the shaping power of language (Cox & Pezzullo, 2016) as well as perspectives on backwards design (Hendrickson, 2006), science communication (Cox & Pezzullo, 2016; Dean, 2009), public participation in scientific research and public understanding of science (Collins & Evans, 2002; Gross, 1994; Rowe & Frewer, 2005), and citizen science (Bonney, Phillips, Ballard, & Enck, 2016; Druschke & Seltzer, 2012; Shirk et al., 2012). Students hear from experts in Rhode Island working on a variety of projects with public stakeholders. At the conclusion of the class, students design and execute a public intervention project that engages some segment of the public in their own research interests. Students have created participatory mapping activities, coordinated public colloquia about global collaboration for fisheries management, and taught lessons to elementary school children about climate change, vernal pools, and soil science, among other activities.

An interdisciplinary course in the Department of Journalism for upper-level undergraduates and graduate students in journalism, communication, and the sciences, Using Multimedia to Communicate Science trains students in advanced skills in multimodal storytelling, including radio, tv, and data visualization. Journalism students improve their multimedia reporting skills and understanding of science, whereas STEM graduate students learn how to effectively communicate their research to the journalists in the class through in class discussions and writing projects that include posters, TED talks, radio and television interviews, and photo slideshows for designated Websites covering the sciences. SciWrite@URI students also learn from reviewing the writing projects of students in journalism and communication, including news reports of STEM poster sessions, coverage of public science lectures, interviews and radio news stories, and photo slideshows for science news Websites.

In addition to coursework, Graduate Science Writing Fellows have opportunities to apply the knowledge and skills they have learned and to gain professional practice writing in multiple genres for diverse audiences by undertaking a writing-intensive internship with an external agency or organization related to their research discipline. Students identify suitable topics and outlets with their internship hosts and engage frequently with Faculty Science Writing Fellows and their peers on developing and revising each piece. Graduate students receive 20 hours per week of graduate pay for the internship work.

Other features of the program include regular workshops, internship poster presentations, and writing boot camps, as well as participation in the new Graduate Science Writing Center. The Center opened in fall 2017, and SciWrite@URI student fellows participate in rhetorically focused tutor training that allows them to assist writers at any stage of the writing process, including planning, researching, drafting, revising, or editing. Tutors are trained to provide general writing support for style, syntax, and grammar, but they emphasize the SciWrite@URI three-legged stool: habitual writing, multiple genres, and frequent reviews. Our intention is that SciWrite@URI tutors will help establish the practice of habitual writing with graduate science writers and make visible the use and impact of frequent reviews. Graduate Science Writing Fellows also make use of their training

in writing for multiple genres, acquired through courses and internships, to aid STEM graduate students interested in communicating their science to external audiences.

Early glimpses at SciWrite@URI's impact

Although discussion of our extensive assessment protocol is in development, we offer a few glimpses here to support the notion that the SciWrite@URI approach seems to be having important impacts on our campus for students, faculty, and the university at large.

In SciWrite@URI courses, we are hearing from students that their rhetorical work is having a positive impact. Students credited Graduate Writing in the Life Sciences for learning about topic sentences, peer review and revision, and audience and forum analysis, and for cultivating a more positive attitude toward writing. On an end-of-semester evaluation that probed students about something they learned that surprised them, many STEM students offered variations of this comment, "I can actually write." One student described Graduate Writing in the Life Sciences as "a nightmare that I needed," thanks to her initial terror about the class's emphasis on habitual writing (writing daily in class and out), frequent peer review (at least two peer workshops for each of the four major writing projects), and multiple genres (submitting a piece of public writing to an actual venue). Another student described creating a postclass peer review group cheekily dubbed "Thursday Shame Club" to laugh through their collective discomfort with sharing early drafts. One student reported renaming his first draft the "This draft just sort of happened" draft. These may seem like small shifts, but for these high-level PhD scientists, many of whom arrived in class with traumatic classroom writing experiences and extremely high expectations for the near-perfection of their scientific research, being able to engage with writing, to share their writing, and to laugh about writing was a major breakthrough.

More subtly, our first cohort of student fellows—thanks in large part to frequent reviews, as well as shared courses and workshops—have become a true cohort and have come to see writing as a social activity. They share work with each other outside of class. They attend public meetings and lectures together on and off campus and voluntarily contribute to each other's fieldwork and research design. They take their dogs to the park together and cook each other meals. Most remarkably, perhaps, they continuously talk with each other about writing.

And they are starting to see some successes. One current student fellow just applied for and received a $2,000 fellowship for geologic research expenses. He explained that this fellowship application was the first he had written and asserted, "I share the honor with the SciWrite@URI program. The knowledge and perspective the program has imparted has been instrumental in progressing my communication skills. I look forward to continuing to become a better communicator." Our students are beginning to get their work published in local magazines and newspapers and are actively pursuing grant applications to support their research.

In short, we're seeing some major advances inside the classroom, as well as out. Our unstructured boot camps, for instance, met one time per week in the fall for 3 hours and, by popular demand, met three times per week in the spring for a total of 11 hours per week in two campus locations. Students even took over running boot camps themselves over winter break. Boot camps have averaged seven participants per session—including faculty from four departments and two colleges and graduate students from four programs—who have spent an average time of 2.4 hours writing per session. Our workshops have also prompted attendees to report feeling more confidence as writers, committing to sharing work with a peer or colleague, maintaining a consistent writing routine and writing environment, and creating multiple drafts of a single writing project.

Our SciWrite@URI faculty, too, are making great strides, engaging rhetorical terms and concepts in their courses and working to incorporate the principles of habitual writing, multiple genres, and frequent reviews in their syllabi. One early standout has been a faculty fellow involved in the university's professional master's program in environmental science and management. After noticing that many students in the professional master's program had been waiting until their final semester

to work on the major papers required for their degree, he embarked on an ambitious plan to revamp writing instruction throughout the 2-year master's program. In addition to emphasizing rhetoric and writing in his seminars with program students, in just his second semester as a faculty fellow, he substantially revised his first-year student seminar to introduce a new "pitch presentation" for students to present early major paper ideas in a more concrete and accountable way and to incorporate a peer review process into pitch presentation development. He has also been stitching peer review and major paper chunking into student seminars throughout students' 2nd years in hopes that this new group of professional master's students will graduate in spring 2018 with powerful and polished major papers.

Although most faculty fellows are not necessarily making changes at the programmatic level, other faculty fellows have been actively revising their current courses to incorporate chunking and peer review. For instance, one faculty fellow credited those changes to improving the average grade for final papers in her graduate biochemistry methods course this past fall.

Challenges and opportunities for growth

We have been thrilled to see some of these early results of the program, but we are continuing to adapt the program. Although the SciWrite@URI framework we offered to the NSF, back in 2015 when the initial grant was awarded, provided a solid foundation for the work we have accomplished over the first 2 years of SciWrite@URI, our work has not been without its challenges. We offer a synthesis of those challenges here, and some tentative suggestions for addressing them, in hopes that other cross-disciplinary teams considering implement rhetorically focused STEM graduate training might learn from our experience to date.

Recruitment of graduate students and faculty for SciWrite@URI was challenging, though not in the ways we might have anticipated. Although there was certainly interest on campus in the program, it is difficult to recruit graduate students to invest in a 2-year (including one summer) intensive program that is complementary but additional to their research and other obligations, including fieldwork and teaching. The summer internship pay is an incentive for SciWrite@URI students; they currently receive no assistantship or stipend during the academic year from the program, which means that they are largely participating without pay. Student interest was (and is) high in the program, but students need to convince their major professors that participation is a worthwhile investment of time and energy that would otherwise be spent directly on their scientific research. Depending on the support (or lack thereof) of a major professor, the timing of field seasons, and other demands, many students might want to participate in the program but simply are not able to. Because time management will continue to be a challenge for student recruits, we have tried to address that head-on by incorporating a focus on time management and prioritization in some courses. As to the larger challenge of advisor support, we are already seeing more faculty on campus express enthusiasm for the program and direct students to us. We expect this enthusiasm will build as our university begins to see more of the benefits of participation for students and faculty.

Logistical challenges of SciWrite@URI, too, should come as no surprise to anyone who has run a committee or program, but they sometimes seem acute. Scheduling around student classes and office hours—across multiple graduate programs and colleges—is an ongoing struggle, compounded by some of the workshops we hold for SciWrite@URI students and faculty. Although we have been happy to see the rich interactions those joint sessions have fostered, we recognize the challenge of scheduling even our twice-a-semester two-on-one coaching sessions with faculty fellows. We encourage other faculty hoping to adopt similar programs to finalize the scheduling of each semester's activities at a group session at the beginning of the semester. Scheduling group activities while we are all together—SciWrite@URI team, student fellows, and faculty fellows and mentors—has helped to get us together more consistently and easily.

These logistical challenges extend to our work on the leadership team, of course. Our program depends on the deep commitment of five faculty members from a variety of disciplines who are also committed to other NSF and non-NSF grants, running major programs at the university, going on sabbatical, teaching at the undergraduate and graduate levels, doing their own fieldwork, and traveling for conferences and speaking engagements. We have been able to address those challenges, in part, by assembling a complementary team with different levels and types of experience from different parts of the university. Because we had worked together in various groupings before we came together to develop SciWrite@URI, we knew we could work well together. Many of us had expressed specific interest around the connections of rhetoric, writing, and STEM graduate training for a number of years before the request for proposals came out from NSF, so these logistical challenges were met with a more dynamic range of potential solutions from colleagues who shared a good amount of enthusiasm, generosity, and goodwill.

Sustainability requires that in the midst of balancing logistical details, our program team spends a significant amount of time and energy on working to convince university administrators that our 3-year federal grant and the seed of our ideas are worth investing in over the long term. We must be champions, advocates, and advertisers of SciWrite@URI while teaching its classes and workshops, recruiting its fellows, managing its budget, and assessing its efficacy. One of the reasons we have been somewhat successful at that work thus far is that we knew at the start that this was an initiative that would resonate with our administrators; that our team represented a small cross-section of the university, including multiple departments and colleges; and that we coordinated closely with the Graduate School. It helped that we solicited letters of commitment from key administrators when we first submitted the grant in early 2015. It also helped that we created and added new SciWrite@URI courses to the university catalog, rather than just relying on more fleeting workshop-style training, thereby infusing SciWrite@URI into the structure of the university. We are also in the midst of creating a graduate certificate program—open to SciWrite@URI fellows and nonfellows—that will help make the program and its impacts more visible and durable on campus.

A kairotic moment for STEM training in rhetoric

Despite the challenges of this work, this is exactly the right moment for rhetorical studies to be exploring our possible collaborative contributions to scientific writing, science communication, and public outreach and engagement. The NSF, along with other major funding organizations, increasingly insists that applicants pay close attention to designing for the broader impacts of their work. As NSF (n.d.) describes, the broader impacts of a proposed project refer to its work beyond research to "advance discovery and understanding while promoting teaching, training, and learning"; "broaden participation of under-represented groups"; "enhance infrastructure for research and education"; "broaden dissemination to enhance scientific and technological understanding"; and "benefit [. . .] society" (). Despite NSF's push for scientists to plan for and implement activities that will yield broader impacts of their science to society, this essential criterion of NSF-funded projects remains relatively undefined (Skrip, 2015), leaving much room for consequential collaborations between rhetoricians and scientists.

Graduate education in STEM disciplines has traditionally focused on ensuring that students have obtained a comprehensive knowledge of discipline-specific subject matter and skills in the techniques associated with that discipline. We contend that this disciplinary knowledge and skill set must include deep knowledge of effective communication praxis, without which graduate students cannot function as true professionals in academia or private industry. SciWrite@URI, and programs like it, have the potential to transform STEM education by enhancing the agency of two distinct groups: (1) graduate students who are as adept at the fundamentals of their science as they are at communicating that science to diverse audiences including other scientists, government officials, businesspeople, practitioners, policy makers, and the public, and (2) faculty who are comfortable and confident regularly embedding rhetorical practice in their pedagogy and advising and moving through their

own writing process with greater efficacy and consequence. What rhetorical training adds to this process is to create current and future scientists who can envision their scientific practice as discursive, social, communal, and consequential.

Based on what we are already seeing in SciWrite@URI, graduate students' newly developed writing and communication skills translate to broader impacts within the university and should transfer to wider communities after students graduate. The model we have offered here equips participating students to communicate science and engage with diverse audiences regardless of the career path they choose. Specifically, it ensures that students who pursue research-related or nonresearch careers can communicate their work in a style and form that is accessible and consequential for their specific audiences and discourse communities. Graduate Science Writing Fellows undertake internships that offer venues, such as Websites, newspapers, and social media, for putting their new knowledge and skills to practice. Using their training and through these venues, they communicate their science to the public using styles and language that are accessible to the target audience. Graduate students enrolled in classes with enhanced writing objectives are encouraged to submit their writing to public forums. In each case, graduate students at our university now have opportunities to practice engaging with publics around their scientific interests, thereby increasing science literacy locally. Most SciWrite@URI graduate students in one capacity or another will launch into careers that offer opportunities for engagement with the public, thus providing avenues through which these program alumni can work to increase scientific literacy in interested citizens. As students tend to travel away from their graduate institutions in seeking careers, this ability to engage with the public and contribute to science literacy will extend to communities beyond that in which our university is embedded.

Faculty Science Writing Fellows and Mentors, too, are developing new knowledge and skills in teaching writing for diverse audiences through faculty workshops in habitual writing, multiple genres, frequent reviews, and other training opportunities, and the broader impacts from those activities are expected to be expansive. These faculty are integrating a new approach in their graduate classes in which a variety of writing exercises are initiated early, often, and with many opportunities for review and revision that extends our approaches to graduate students who are unable to participate as Graduate Science Writing Fellows. In addition, participating faculty initiate these approaches with the graduate students that they advise. Importantly, given the career spans of many faculty, these approaches will be continually propagated in existing and new classes thereby affecting annual cohorts of graduate students for decades. We encourage Faculty Science Writing Fellows and Mentors to act as ambassadors for this new model and help build capacity within our faculty ranks by sharing these approaches with others internally and externally. SciWrite@URI faculty are also using this training to increase their engagement with the public around their own scientific research, which should lead to increased science literacy in the local community and beyond and potential impacts on community health and well-being.

As we move into the 3rd year of the program as of this writing, we hope to continue to emphasize these broader impacts for students and faculty and look ahead to future expansion of the program. We will continue our program's commitment to recruiting and retaining students and faculty from under-represented groups, and part of our expansion will come through finding ways to more deeply integrate and better support ESL graduate students on campus into the program. We know from the literature and our own experience that it is particularly important for ESL graduate students to engage with their advisors throughout the writing process, well before a first draft of a thesis or dissertation is completed. Graduate students with faculty advisors who worked more closely and collaboratively with them achieved stronger engagement in their research community of practice and more successfully negotiated writing demands related to their dissertations (Belcher, 1994; Braine, 2002). We believe that our program emphasis on training faculty advisors to work with their graduate students early and often in the writing process and to establish writing as a collaborative process between advisor and advisee will have a positive impact on ESL graduate students, who, in particular, benefit greatly from one-to-one assistance with their writing process (Braine, 2002).

Although much of our program revolves around rhetorical training and practice in small- to medium-sized groups, including workshops, classes, and internships, the Graduate Science Writing Center provides a venue and trained graduate student peers to provide one-on-one writing consultation and assistance. Meanwhile, the SciWrite@URI summer internship could position future ESL student fellows to leverage their L2 abilities off campus (Cox, 2010), and the program's focus on writing for different audiences could help ESL students overcome traditional writing assessment challenges (Janopoulos, 1995).

This work is already ushering in important changes in culture and structure on our campus, but we recognize that the impacts of this new model must extend beyond our university and beyond the length of the grant to truly transform STEM education. Consequently, we are in the process of formative and summative assessments using multiple forms of evidence and measures. Ongoing assessment results contribute to our backwards design approach (Wiggins & McTighe, 2001) and inform our status as a national model for science writing and science communication pedagogy. Future publications will describe the assessment process in greater detail, demonstrating how a mixed methods approach using standardized rubrics, Qualtrics surveys, Eli Review data, and student and faculty writing reflections enables us to chart the growth of our participants' confidence and expertise and adjust our curriculum to meet the needs of the local community. True to its grounding in rhetoric, SciWrite@URI will continue to adapt to its changing ecologies, offering a scalable model for STEM education that creates better science writers—and better scientists—through rhetoric.

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