Scientific Writing Workshop Improves Confidence in Critical Writing Skills among Trainees in the Biomedical Sciences

Emily Wortman-Wunder[1] and Inge Wefes[2]*

[1]*Department of English, University of Colorado Denver, Denver, CO 80217-3364;*
[2]*University of Colorado Denver Anschutz Medical Campus, Aurora, CO 80045*

Written communication is a key research skill, yet the current model of pre- and postdoctoral training in the biomedical sciences lacks consistent formal training in this area, leading to crises of confidence when tackling research writing. A 15-hour non-credit workshop, "Secrets of Successful Scientific Writing," was developed in collaboration with an experienced instructor of scientific writing. The workshop consisted of six 2.5-hour sessions and was offered six times; a total of 126 trainees attended over these six offerings. Topics included strategies to engage the audience, principles of psychological linguistics to maximize sentence effectiveness, conventions of biomedical journal writing, technical writing and the history of scientific publishing, and two sessions on grant writing. Student confidence in and familiarity with targeted writing skills were assessed by self-evaluation questions administered immediately before and after each session. The workshop was determined to be effective at improving the confidence of participants regarding specific writing skills in the biomedical sciences, with all but two of the measures showing that the workshop had a large effect size. We conclude that a short, structured workshop can help improve the confidence and knowledge of pre- and postdoctoral writers, preparing them to better meet the writing challenges of their professional careers.

INTRODUCTION

Scientific writing is an essential workplace skill for biomedical researchers (1), yet its teaching is most frequently ad-hoc and informal at the graduate level, taking place within the apprenticeship culture of individual laboratories (2–6). This lack of formal training has led to uneven preparation in professional writing skills, resulting in inadequate publication and productivity rates and lack of confidence both in writing and in supervising other writers (5–7).

Effective written communication is consistently identified as a core workplace ability (8, 9), and programs that successfully develop this skill have become more desirable for both employers and funding agencies. A key component of effective writing at the graduate and postdoctoral level is writing self-efficacy, or confidence in one's ability to successfully complete the required tasks (10, 11). However, graduate writing instruction often neglects this component, particularly in the early years of a training program (12–14). The work of Shah *et al.* (3), Catterall *et al.* (4), Cameron *et al.* (5, 6), and others, as well as our own observations, indicate

that the writing feedback most frequently offered to PhD students by research faculty emphasizes assessment over instruction in principles. Anecdotally, instructors admit that they often evaluate student writing skills without articulating how to achieve or improve those skills. Such imprecise or incomplete feedback can erode confidence and impede progress, leading to lower dissertation completion rates, lower publication rates, and higher graduate program dropout rates (3, 11, 14).

While it is generally agreed that structured writing classes alone are insufficient to produce significant changes in trainees' writing ability, they can provide a useful meta-language and formal introduction to the conventions of biomedical writing and can help improve both familiarity with rhetorical concepts and writing self-efficacy, producing writers who are more ready to be successful (3–6, 10, 11, 14). However, the biggest challenge for providing such training for pre- and postdoctoral fellows in the biomedical sciences is the heightened competition for time. There have been few studies that assess the value placed by biomedical faculty on the development of beyond-the-laboratory skills, including writing. Watts *et al.* (15) found, in a survey of 817 faculty at seven institutions, that, while most respondents acknowledged the urgent need for such skills, faculty definitions of which skills were most critical varied widely, as did their assessment of the number of hours per month that should be dedicated to their development. As with all skill development, a minimum of time investment and practice is necessary to make an improvement stick and to enhance the

self-efficacy of the trainees. Previous studies have looked at writing retreats and establishing writing groups (1, 5, 7), but to our knowledge, none have looked at the effectiveness of short courses to increase writing confidence.

A few institutions have addressed deficiencies in the writing of their science graduate students in a comprehensive and systemic way (16); however, most universities have cobbled together a patchwork of corrections and emergency assistance that neither address the underlying problems nor help students in a consistent way. From this perspective, the writing instruction options that are currently available to students at the University of Colorado Denver|Anschutz Medical Campus are typical. Over the past decade, some programs have developed formal writing interventions, including a small-group, five-student course on Hypothesis Development and Experimental Design offered by the Cancer Biology PhD Program and a graduate-level scientific writing class in collaboration with the College of Liberal Arts and Sciences' English Department. The latter course is required for Biomedical Sciences and Biotechnology Master's students, but this requirement has not been widely adopted by PhD programs. Finally, the CU Denver|Anschutz Writing Center offers one-on-one feedback but little formal instruction and tends to address or remedy acute rather than systemic needs. None of these options is positioned to help large numbers of trainees in the biomedical sciences on the Anschutz Medical Campus.

Our hypothesis is that a basic instructional workshop in written scientific communication implemented by an expert in writing instruction can increase the writing self-efficacy of novice researchers as well as their familiarity with the instructional content, thus empowering them to more effectively tackle the complex writing tasks they face (10). To this end, we developed a 15-hour workshop in scientific writing called "Secrets of Successful Scientific Writing," which was sponsored by the NIH Program for Broadening Experiences in Scientific Training (BEST) (17). This program provides funding to 17 institutions in the United States to experiment with training opportunities and develop best practices that make pre- and postdoctoral trainees in the biomedical sciences more competitive for jobs inside and outside academia. We measured the course's effectiveness by administering self-evaluation questions assessing the trainees' self-efficacy regarding their writing skills before and after each of the six workshop units.

METHODS

The University of Colorado Denver is a dual campus university, with the majority of undergraduate training and Master's training being offered on the Denver Campus, and almost all pre- and postdoctoral training in the biomedical sciences being offered on the Anschutz Medical Campus. The Anschutz campus annually trains about 400 pre- and 400 postdoctoral fellows in the biomedical sciences, each of

whom can select from a variety of workshops that the BEST Program offers on topics such as leadership development, project management, public speaking, and critical thinking, in addition to scientific writing.

In keeping with the funding source (18), the workshop primarily targeted PhD students and postdocs in the biomedical sciences, but, if seats were available, it was also opened to other people on the Anschutz Medical Campus, including faculty. The 15-hour (weekly 2.5-hour sessions) learning opportunity was offered without cost for participants and on a voluntary basis without academic credit (Table 1). However, participants who took part in at least five of the six sessions earned a Certificate of Participation issued by the BEST Program. The instructor was a faculty member from the English Department with long-standing experience in teaching scientific communication. Each workshop session focused on a different topic, and the delivery format was a combination of lectures, group discussions, and in-class writing exercises. An accompanying workbook, designed by the instructor, contained examples for analysis, exercises, and some bedrock principles. Feedback on students' works-in-progress was provided on a volunteer basis, either during sessions (students and the instructor would describe what is working and offer advice for improvement) or in writing from the instructor between sessions. To assess the impact of the workshop sessions while keeping the burden on participants minimal, participants were asked to complete short surveys regarding their confidence and familiarity with the material before and after each workshop session.

Informed consent for research involving human subjects

The only human data that are included here are the responses to the pre- and post- evaluations for each class. These data are presented anonymously. The Colorado Multiple Institution Review Board (COMIRB) has reviewed the grant that sponsored the study, including the related publication, and it did not find any ethical concerns. COMIRB has therefore declared that the study has Institutional Review Board exempt status.

Data collection and analysis

Workshop participants rated their confidence in and familiarity with various scientific writing skills before (pretest) and after (posttest) each workshop session (Table 2). The form asked them to rate the qualities on a scale of 1 to 4, clarifying that 1 = not at all, 2 = hardly, 3 = somewhat, and 4 = a lot, very much, or very well, depending on the kind of question. Following the recommendation of CU Denver's Director of Assessment as well as the CU Office of Institutional Research, we decided to use a four-point scale for the assessment, thereby insisting that workshop participants reflect on the value of the instructions and come at least to a tentative judgment. Of 24 skills, 17 (71%) were related

TABLE 1.
Topic and objectives of each of the six sessions of the workshop.

Session	Topic	Objectives
Day 1	How to make writing more engaging and memorable (19, 20)	• Elements of a story and how to use them to make scientific writing more effective • "Sticky" stories and how to make writing more memorable • How to create more effective openings • How to create openings that target different audiences
Day 2	How to make writing more clear and more effective at the sentence level (21, 22)	• General principles about how the brain processes language • Applying knowledge of language processing to make writing easier to process • Harnessing the power of grammar
Day 3	Conventions of journal papers in biomedical sciences (21)	• Structure and function of sections (Introduction, Methods, Research and Discussion) of a journal paper (the "IMRAD" paper) • Challenge, action, and resolution • Review: Why tell this story now? • Writing in units
Day 4	Technical writing, addressing an audience, and understanding the history and future of scientific writing	• History of scientific publishing • Citational communities • Technical writing and audience analysis • Technical writing employment strategies • Drafting and revision: problems and strategies
Day 5	Proposal writing: general principles	• Key elements of a successful proposal • Importance of audience • Importance of real estate (location of material)

Day 6	Proposal writing: focus on NSF and NIH (23)	• Brief history of NSF & NIH
		• NSF
		    Intellectual Merit Broader Impacts
		• NIH
		    Research Strategy Innovation
		    Significance Approach

NSF = National Science Foundation; NIH = National Institutes of Health.

to confidence, and 7 (30%) were related to familiarity. The internal consistency as indicated by Cronbach's alpha was 0.9822 for confidence and 0.9709 for familiarity. Pretest ratings were compared with posttest ratings to determine the effect of the workshop on these skills for each participant; effect size was interpreted following Cohen (24). Briefly, the averaged pretest scores were subtracted from the posttest scores and then divided by the averaged standard deviation, with 0.8 being a large effect size, 0.5 being medium, and 0.2 being small (24). Mean rating (x), standard deviation (SD), t-statistic, and p value were calculated. Our analysis includes the data sets of six consecutive workshops, reaching a total audience of 126, of whom 75 attended enough sessions to be awarded a Certificate of Participation.

RESULTS

Overall, participants reported an increase in confidence regarding specific writing skills and in familiarity with key writing concepts based on pre- and post-workshop surveys. All of the self-evaluation assessments of familiarity, and all but two of the self-evaluation assessments of confidence, showed a large effect size (Table 2). All increases in pre- to post- were statistically significant and showed a shift from lower to higher ratings of participants' confidence and knowledge. The skills about which participants reported the greatest increase in confidence included those related to grant writing (Table 2, Sessions 5 and 6). The areas in which participants reported the greatest increase in familiarity, meaning that they reported little knowledge before the workshop and high knowledge after, were rhetorical concepts and revision techniques, some of which were also related to grant writing (Table 2, Sessions 2 and 5).

The skills that showed the smallest increase in self-efficacy before and after a session, as measured by effect size, were those about which students reported feeling confident or knowledgeable about already at the beginning of the session, such as having a good understanding of where their publication and writing activities fit into the larger world of scholarly communication (Table 2, Session 4).

DISCUSSION

The results of before and after questionnaires for "Secrets of Successful Scientific Writing" indicate that a short and focused workshop can improve confidence in

TABLE 2.
Self-assessment evaluation questions were asked immediately before and after each session.

	Pre			Post			t	Effect size
	x	SD	N	x	SD	N		
Session 1								
I can strategically employ the elements of a story in my scientific writing.	2.09	0.71	91	2.87	0.88	90	6.57	0.98 Large
I know how to make my scientific story "sticky."	1.60	0.63	91	2.68	0.95	98	9.28	1.37 Large
I know what makes a paper publishable and more likely to be cited—and I know how to revise my own work to make it more effective in these areas.	2.03	0.86	115	2.78	1.00	115	6.09	0.81 Large
I know how to emphasize different aspects of my scientific argument depending on the audience I am trying to reach.	1.97	0.73	89	2.58	1.05	102	4.73	0.69 Large medium
Session 2								
I can identify the stress position in a sentence or paragraph.	1.83	0.84	72	3.28	0.70	72	11.24	1.88 Large
I can identify the topic position in a sentence or paragraph.	2.19	0.77	70	3.28	0.62	88	9.70	1.57 Large
I can exploit the stress position, left-to-right reading, and other information processing techniques to enhance the clarity and directness of my writing.	1.77	0.87	91	3.00	0.97	98	9.14	1.34 Large
If my goal is to make my reader's job as easy as possible, I know where and what to change in my scientific writing while remaining true to the conventions of the genre.	1.59	0.69	70	2.90	0.98	84	9.78	1.57 Large
Session 3								
I can clearly articulate the different goals and strategies for each section of a scientific technical report, and I can adjust these goals and strategies based on my research findings and my target journal.	2.07	0.64	75	3.0	0.80	75	8.23	1.29 Large
I can use basic narrative principles to draft, assess, and revise the sections of my technical reports.	1.91	0.70	76	3.02	0.90	62	7.97	1.39 Large
I am confident in my ability to match the scope of my paper's introduction to the scope of its resolution.	2.01	0.78	72	3.08	0.83	78	8.05	1.33 Large
I can use an abstract schema of the shape of my paper's content to assess the effectiveness of its opening and resolution.	1.73	0.69	74	2.84	0.90	77	8.54	1.40 Large

I am familiar with the says–does chart as a way of assessing the logical flow of a piece of writing (or as a revision technique for my own writing).	1.36	0.63	72	3.01	0.96	67	11.88	2.08 Large
Session 4							
I am familiar with the Open Access movement and what it means for my publishing opportunities, and the pressures that led to its development.	2.13	0.89	67	3.04	0.90	71	5.96	1.02 Large
I am familiar with the subscription pressures faced by my institutional library.	1.60	0.81	65	3.07	1.00	70	9.46	1.62 Large
I have a wide range of drafting and revision techniques at my fingertips and I have recently compared notes on the topic with colleagues.	1.95	0.65	65	2.90	0.79	69	7.55	1.32 Large
I have a big-picture understanding of where my publication and writing activities fit into the larger world of scholarly communication.	2.27	0.82	89	2.89	0.90	88	4.75	0.72 Large Medium
Session 5							
I can list the key elements of a strong research proposal.	2.08	0.67	76	3.15	0.81	74	8.86	1.45 Large
I can effectively assess my writing to determine if my research proposal meets the guidelines for a strong research proposal.	1.88	0.76	77	3.09	0.78	74	9.67	1.57 Large
I am familiar with the concept of proposal real estate and how to exploit it to increase the likelihood of funding.	1.43	0.71	77	3.12	0.87	75	13.08	2.14 Large
I know how to use the principles of effective storytelling to increase the chances of getting my proposal funded.	1.78	0.75	77	3.17	0.73	69	11.37	1.88 Large
Session 6							
I am familiar with the history of scientific funding in the U.S.	1.54	0.65	50	2.90	0.63	48	10.54	2.13 Large
I am confident that I know what NSF reviewers want when they ask me to describe the intellectual merit of a particular project.	1.56	0.70	50	3.02	0.67	48	10.54	2.13 Large
I am confident that I know what NSF reviewers want when they ask me to describe the broader impacts of a particular project.	1.78	0.73	51	3.08	0.71	48	8.98	1.81 Large

Participants were asked to rate their answers on a scale of 1 to 4, meaning: 1 = not at all, 2 = hardly, 3 = somewhat, and 4 = a lot, very much, or very well, depending on the kind of question. Mean rating (x), standard deviation (SD), number of responses (N) for each question, and t-statistic (t) are indicated. The table includes assessment data from all six times the workshop was offered. NSF = National Science Foundation.

and familiarity with key scientific writing skills, especially those surrounding one of the most anxiety-inducing scientific writing activities, grant writing. Four of the five largest effect sizes were for skills associated with this type of writing (Table 2).

Confidence in one's ability to perform a skill, or self-efficacy (10), has been shown to be an important component of the writing process, from elementary school through pre-professional training (25–27). Increasing writing self-efficacy has been shown to lessen writing anxiety (11, 25, 28), improve writing productivity (14, 29), and, in the case of graduate students who speak English as a second language, improve performance (30). While some studies with undergraduates have found factors other than confidence to have a greater influence on writing ability (31, 32), research with doctoral students consistently identifies confidence as a critical predictor of success. For example, Lonka *et al.* (33, 34) found that perfectionism, procrastination, and frustration related to writing were predictive of higher levels of stress and lower productivity among Finnish PhD students, and that these negative feelings were often related to confidence. A similar study among PhD students in Spain found that the students who had the most frustration with writing were likely to be the least successful in their doctoral program (35). A workshop that helps to improve confidence in writing skills, such as the "Secrets of Successful Scientific Writing," may lower frustration, anxiety, and fear related to writing.

Similarly, lack of familiarity with the conventions of scientific writing has been shown to impede the writing progress of novice researchers enrolled in graduate programs in medicine (3). Doctoral students who self-identify as underprepared in academic writing report that this lack of preparation makes it difficult to be fully independent as novice researchers (36). Furthermore, while this lack of preparation can be overcome by direct instruction (36), many advisors of PhD students report that they lack the time or the skills to instill such knowledge (6, 37). Increasing familiarity with scientific writing conventions has been reported to improve writing confidence and self-assessed proficiency among doctoral students (29), and an intense, focused delivery of non-discipline-specific writing instruction to graduate students working on theses or dissertations has been shown to improve writing proficiency and research independence as assessed by before-and-after tests (38). Likewise, a study of 510 graduate-level biomedical students in Texas suggests that the development of skills in academic writing can improve research engagement and likelihood of program completion (39). Trainee self-assessments for our workshop indicated that it increased their familiarity with the skills and conventions of biomedical writing as well as their confidence.

Taken together, our results indicate that a short, focused workshop in the skills and conventions of scientific writing taught by a writing professional may improve confidence and research readiness in a cost-effective and time-efficient way. However, our evaluation may have some limitations. First, the participants in this voluntary workshop were self-selected and may have been predisposed to find the coursework valuable. In addition, many were actively engaged in writing: several trainees mentioned that they were currently working on a piece of professional writing, including dissertations, journal articles, and grant proposals. Therefore, their inclination to find value in the workshop might have been impacted by their immediate need. However, the feedback we received encourages us to believe that the value of the workshop is more profound than mere tutorial assistance.

There are challenges to designing a workshop of this nature. It is widely accepted that the most effective way to develop writers at the graduate level is through developmental feedback from supervisors (4). However, the structure and the number of participants of this workshop did not allow for extensive personalized feedback, nor did the workshop extend long enough to accompany participants on any substantial part of their development as writers. These drawbacks were addressed in a few ways during the workshop. First, students were encouraged to share writing they were working on outside of the workshop. Second, every class included opportunities to practice the skills just learned and to discuss the process with one or two partners during the workshop. Finally, there were multiple opportunities to discuss common frustrations with the writing process and to exchange strategies for addressing these frustrations. This workshop functioned also as a tool that participants could use to leverage writing instruction and feedback they had received or were receiving from other sources.

Certain issues arose during the development of the workshop and were addressed by adjusting the course content in subsequent workshops. The most substantial modification was the increase in 2016 from five sessions to six. Material has been added or modified in response to feedback, and some initial approaches that were less appreciated, such as the freeform workshopping model typical of creative writing seminars, were replaced with the current model that mixes lecture with in class writing practice and small group and large group discussions (Table 1).

CONCLUSION

The central achievement of this 15-hour writing workshop has been the improvement in participant confidence related to key writing skills and in participant familiarity with key rhetorical concepts at all stages of their research careers. This training can be said to have increased self-efficacy related to biomedical research writing and will empower participants to take on future writing challenges with less hesitation and more success.

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