

Enhancing Graduate Student Communication to General Audiences through Blogging about Nanotechnology and Sustainability

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Supporting Information

ABSTRACT: We have developed and assessed a multiauthor science blog on the topic of nanotechnology and sustainability as a tool to improve the written communication and public engagement skills of graduate students. Focus group studies revealed that after participation in the blog, student authors felt more confident and capable of communicating technical topics to general audiences. Students' research mentors viewed this as an important component of their students' education, as indicated by survey data. Important design aspects of this effort include participation of an editor as well as having flexible content and target-audience guidelines. We have explicitly outlined aspects of the effort we see as critical in order to enable others to replicate this model in related settings.

KEYWORDS: Graduate Education/Research, Curriculum, Public Understanding/Outreach, Communication/Writing, Internet/Web-Based Learning, Professional Development, Nanotechnology



INTRODUCTION

While research provides the foundation of graduate training in the sciences and engineering, numerous reports have recognized that successful careers within and outside academia require development of a broader skill set that includes communication, leadership, and teamwork.^{1–5} The increasing diversity of the doctoral employment landscape calls for institutions of higher education to provide increasingly diverse graduate training.⁵

The 2012 American Chemical Society report on graduate education in the chemical sciences recognized effective communication as one of the critical aspects of professionalism with which graduates should emerge. That same report highlighted the lack of training currently provided to graduate students to develop their ability to “communicate complex topics to both technical and nontechnical audiences.”²

Numerous efforts have been undertaken to address this challenge, both at the graduate and undergraduate levels. The primary interventions designed to meet this need are the integration of writing and presentation modules into existing courses,^{6–11} creation of courses, seminars, or workshops aimed

solely at increasing communication skills,^{12–16} and hands-on experiences in K–12 classrooms or science museums with the aid of tabletop activities.^{17–19}

This article describes the development, implementation, and assessment of an intervention that is directly linked to students' research. This intervention involves intense one-on-one editing, is ongoing for the duration of students' participation with a research center, and takes advantage of online communication technology in the form of a science blog.²⁰

We begin with a brief review of blogging in the education literature, followed by an introduction to the Center for Sustainable Nanotechnology. We then discuss our blog, from development to evaluation. Finally, we conclude with lessons learned and tips for those wanting to implement their own multiauthor blog. We believe this information will be useful to research centers, research groups, department heads, and educators of science students and practicing scientists.

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BLOGS IN SCIENCE AND EDUCATION

Web logs, or blogs for short, are playing an increasingly important role in science and education.^{21–24} The typical format for a blog involves discrete entries (or “posts”) displayed on a web page in reverse chronological order—most having functionality allowing for readers to leave comments or questions on blog posts. Blogs require creation of new posts on a regular basis, and so present a unique opportunity to provide students with repeated written communication experiences.

CENTER FOR SUSTAINABLE NANOTECHNOLOGY

The Center for Sustainable Nanotechnology is a National Science Foundation Center for Chemical Innovation (CCI). The Center is not physical in nature, but is instead a focal point for collaboration that links the complementary expertise of a variety of researchers to achieve what none could do in isolation. This CCI is an integrative partnership program that spans five universities and one national laboratory: University of Wisconsin—Madison, University of Wisconsin—Milwaukee, Northwestern University, University of Illinois at Urbana-Champaign, University of Minnesota, and the Pacific Northwest National Laboratory. The goal of the Center is to use fundamental chemistry to enable the development of nanotechnology in a sustainable manner, for societal benefit. The Center hopes to achieve this by investigating the primary molecular mechanisms by which nanoparticles interact with biological systems.

The Center is currently composed of 7 principal investigators, 1 staff member, 4 postdoctoral fellows, 18 graduate students, and 9 undergraduate students. Center members have a diverse set of skills and research interests. Of the Center’s 40 members, approximately 50% are women and 10% are underrepresented ethnic minorities in STEM (American Indian, Black, and Latino).

ASSESSMENT METHODS

Participant experiences were assessed using a mixed method research design with iterative data analysis (University of Illinois IRB Approval #14026).²⁵ The three data collection methods included a preblog survey, two focus groups, and a research mentor survey.

All Center-affiliated researchers completed a survey after they participated in a blogging seminar. Questions probed their initial interest in blogging, their thoughts about blogging to nonscientifically trained peers, and what they perceived as the barriers to successfully blogging. The 14-question survey included eight close-ended Likert response questions (i.e., answers of *strongly disagree* to *strongly agree*, rated 1 to 5) and six open-ended questions. Survey results were analyzed using descriptive statistics. The full survey along with close-ended response results can be found in the Supporting Information.

Two 30-min, semistructured focus groups were conducted to assess student experiences, reactions, and opinions related to the blog. These were conducted only once, after each student participant had written one blog post. In part to maximize the candor of student responses, students were informed that personal identifiers associated with information from these focus groups would be removed prior to being viewed by Center members not affiliated with the assessment team. These multisite focus groups were conducted with 9 students (50% of total students at that time) via videoconference. A protocol was developed for and followed during both focus groups to prompt interviewees to ensure that the relevant topics were

covered. Questions in both focus groups queried the impact of the blog on students’ ability to communicate to the general public, the blog editorial process, and student initial expectations related to the blog. Our IRB approval does not explicitly allow disclosure of the full focus group transcripts.

Discourse from both focus groups was transcribed. Focus group data were analyzed from a postpositivistic perspective in which researchers attempted to minimize their biases. A thematic approach²⁶ was used in the analysis of the qualitative data. The authors individually coded focus group transcripts and open-ended survey responses and then came together for consensus building and theme development. Student comments were considered representative when at least three separate students commented similarly about the same topic.

Students’ research mentors completed a survey after 16 months of blogging. Questions probed their opinion of the quality of their students’ writing and the value of the blog to their students’ education. The 4-question survey along with complete results can be found in the Supporting Information.

BLOG DEVELOPMENT

Overview

We at the Center for Sustainable Nanotechnology have developed a blog, with the dual purpose of enhancing the communication skills and experience of Center-affiliated students and increasing public interest in and knowledge of science related to sustainability and nanotechnology. This contribution describes the professional development aspects of the blogging effort. The blog has been created, maintained, and publicized solely by Center members. All Center-affiliated graduate students, postdoctoral fellows, and principal investigators contribute regularly to this blog.

Broad Content and Target Audience Guidelines

From the outset, we decided to establish broad and flexible content and target audience guidelines. We hypothesized that in an environment where students felt free to explore and explain topics of interest to them, they would view the creation of blog content not as an assignment but rather as an opportunity to express their creativity and develop their communication skills. Additionally, we aimed to maximize overlap with students’ research goals, so that topics that were relevant to their research would also be topics they could explore in a different capacity on the blog.

Thus, we hypothesized that these flexible guidelines would allow the expectations of academic research, professional development, and public outreach to be mutually reinforcing rather than competing.²⁷ This would enable students to enter the workforce with enhanced written communication skills.

The content guidelines given to the students were that posts on the blog should relate to

- The work of the Center, whether it be an individual’s own research or that of a collaborator
- Sustainability or any topic related to nanoscience or nanotechnology—concepts, applications, news, or research synopses
- “SustainableNano-readiness”—any fundamental concepts that will aid in the understanding of more complex blog content
- The students’ experiences of life as a scientist

We instructed students to envision the target audience for the blog as “their non-scientifically trained friends and family”. We described the target audience in this way to allow students to pilot their blog post ideas on their social circle and maximize

the chance of students getting feedback even with low initial blog traffic volume. This target audience description also provided students with incentives to contribute to the online social networking promotion of the blog by sharing the content with their social circles. We envisioned content being of interest to readers with some pre-existing science knowledge, such as high school and middle school teachers and undergraduate students, as well as the general population.

Student Blogging Introduction

We initially introduced students to the blog project via a 1 h seminar and discussion. The session included a discussion of the target audience and content guidelines. We also discussed the use of plain language (limiting jargon) and active voice as effective communication strategies for general audiences—as opposed to the jargon-laden, passive voice style common in scientific journal articles. At this session we also established participation expectations for the students (see below), introduced the blog editorial workflow (see below), and gave a brief overview of guiding web traffic to the blog via social networking promotion (e.g., Facebook page, Twitter feed, etc.). The blog editor (see below) introduces new students to the blogging process via short videoconference covering the topics outlined above.

Initial Student Survey Results

After this introductory session, all potential blog contributors were asked to complete an anonymous survey (see Supporting Information). Representative responses to initial survey questions are provided in Box 1. When asked what potential

Box 1. Survey Question Topics and Representative Student Responses

Perceived Benefits:

"A better understanding of how to effectively communicate my science to a broader audience"
"Improvement in my ability to not bore my peers"

Blogging to Non-Scientifically Trained Peers:

"I'm excited. I have ideas of what to write about."
"I love communicating to non-scientists."

Barriers to Success:

"Finding time to dedicate to each post"
"I'm not sure that I will be able to write compelling posts"

benefits they perceived, 88% (22/25) of responses referenced improved ability to communicate—both in terms of personal and public benefits. When asked for their thoughts about blogging with their nonscientifically trained peers as the audience, 75% (18/24) of respondents expressed enthusiasm.

In response to a question specifically soliciting perceived barriers to successfully blogging, students expressed two main concerns. First, 48% (11/23) of respondents expressed concern over the time commitment involved. Additionally, 26% (6/23) of respondents were concerned about their ability to come up with topics and write blog posts that would be of interest to nonscientists. Underscoring these concerns, 75% (9/12) of respondents reported never having blogged before.

In summary, students were excited about the idea of creating a blog and saw both personal and public benefits in terms of improved communication. This agrees with other studies on

student motivations for participating in outreach activities.^{16,28,29} Additionally, our data show that students had reservations about time commitment and their level of expertise. These perceived barriers also mirror those found with other science outreach activities.^{14,15,28,29}

■ IMPLEMENTATION

Editorial Process

To alleviate student concerns over lack of ideas, experience, and time, we designed a workflow for the blog that included a Center staff member as a blog editor. The blog editor took the initial responsibility for creating the blog using a free blog web-hosting service.^{30,31} The blog editor is located at one of the 6 Center institutions, reports to the Center director, and communicates with geographically distributed blog participants primarily via e-mail and videoconference. The blog editor is a Ph.D. chemist with an informal background in science writing—having created and maintained one personal science blog and contributed to the development and maintenance of another multiauthor science blog for 4 years prior to the launch of this blog.

The editorial process is the main vehicle through which students develop their written communication skills. The blog editorial workflow mirrors standard editorial practice followed in science journalism.³²

Students begin by writing a pitch (synopsis of an idea for a blog post) to the blog editor. This step provides an opportunity for the editor to help students craft, focus, and narrow story ideas to save time in the editing process. The main criteria used for pitch acceptance are as follows:

1. Pitch covers a sufficiently narrow area to allow students to clearly tell the story in the length of a single blog post of 500–2000 words. Often students are encouraged to break up ideas into multiple, more manageable blog posts.
2. Pitch content falls under the content guidelines outlined (see above).
3. Language used in the pitch is appropriate for a nontechnical audience.

After the pitch is accepted, students write a draft blog post and go through one to three editing cycles with the blog editor before finalizing the post. Through this process, the blog editor works to ensure that each post tells a single coherent story and has opening sentences that will catch the attention of a general audience and give a clear idea of the main content of the post. In journalistic terms, this latter point is often referred to as "having a strong lede". In addition, the editor instructs students in other standard science writing techniques such as the use of short sentences, plain language, and active voice.^{33,34}

After each student had written at least one post, we introduced peer editors into the workflow. Using peer editors serves to distribute responsibility for writing and editing blog content and provides editing experience to interested students. In selecting peer editors we focus on students whose writing is especially clear and who express interest in furthering their science communication skills.

Under this modified workflow, student bloggers still go through the pitch process with the blog editor; the editor then assigns the student blogger to one of the peer editors for the drafting process. After one to three cycles of editing, the student bloggers send their edited draft to the blog editor for final edits and publication. Blog post drafts that have been

Table 1. Selected Blog Posts and the Scientific Topics They Cover

Post Title	Topics Covered
"Laser Science. Light Can Do Way More Than Just Bend"	Refraction; Phases of matter; Electromagnetic spectrum; Nonlinear optics
"Zooming in on the Nano World: Limitations and Breakthroughs in Light Microscopy"	Diffraction; Fluorescence; Super-resolution fluorescence microscopy
"How to Avoid Bitter Coffee and Why it Exists in the First Place—A Scientific Look at Brewing"	Properties change with size; Diffusion; Solubility; Extraction
"The Canary in the Coal Mine and a Whole Lot More: The Reproductive Habits and Scientific Utility of the Water Flea"	Sexual and asexual reproduction; Population dynamics; Toxicology; Environmental genomics

edited by peer editors typically need some further edits, but are markedly improved compared to nonpeer-reviewed drafts. As an added check for blog post quality, students send the finalized blog posts to their research advisors prior to publication.

The time required for the editing process varies, depending largely on the scope of the post and the author involved. Prior to implementation of peer editing, each post consumed approximately 1–3 h of the editor's time—from post conception to published post, including all necessary editing, fact-checking, image sourcing or creation, online formatting, and social networking promotion. After peer editing, this time was reduced to 45–90 min—with the remaining effort being distributed among the peer editors.

Expectations for Students

From the outset, we established the expectation that each student must write 2 to 3 posts per year of >500 words each. This applies to all students performing Center-affiliated research, and they are expected to continue this output for as long as they are associated with the Center.

The blog post output expectation is maintained through a regular calendar system. We adopted this process to ensure students would write posts on a regular basis, which would reinforce their communication skills through continual practice and refinement.

Students' principal investigators were the primary vehicles for enforcing this expectation. They did this by emphasizing the importance of this project at meetings of the Center. They also led by example by regularly contributing blog posts (see below).

Blog Contributors and Post Output

While graduate student professional development was a primary goal of the blog, all Center-affiliated researchers were invited to participate. During the first 16 months of the blog's existence, a total of 71 posts were published. Nearly half of those (30 posts) were written by a total of 16 graduate students. Additional blog contributors included all 7 Center-affiliated principal investigators (14 posts), 4 postdoctoral researchers (6 posts), 4 undergraduate students (5 posts), the blog editor (14 posts), and two guest bloggers (2 posts).

Representative Post Topics

To provide a clearer picture of the types of concepts in which students have gained experience in communicating, we have listed a few blog post titles in Table 1. This table also highlights the scientific topics covered by each of those posts. Perhaps not surprisingly, most students chose to write about topics close to their area of specialization. This shows that the blog functioned in a way to allow overlap between students' research responsibilities and their professional development and public outreach goals.

The first two examples in Table 1 introduce the analytical techniques of nonlinear optics and super-resolution fluorescence microscopy that are used regularly by those researchers,^{35,36} but most of the text of those blog posts is dedicated to describing more fundamental concepts that are critical for understanding

how those techniques work. In the third example, a student specializing in nanoparticle synthesis and functionalization introduced the idea that properties change with size by discussing the taste of coffee as a function of the size of coffee bean particles. The last example shows a post written by a student who specializes in environmental genomics. In that post, among other things the student describes how the model organism *Daphnia magna* switches from asexual to sexual reproduction when the population density reaches a critical level.

ASSESSMENT OF STUDENT EXPERIENCE

After nine months of blogging, we conducted two student author focus groups. Focus group questions included the following.

- "What were your initial thoughts about the blog?"
- "Give me an idea of how the whole blogging process works."
- "How has the blog impacted you in terms of your ability to write and communicate with the general public?"
- "How has this experience impacted you professionally?"

Four major themes on student outcomes were identified from focus group data, including (1) valuable writing experience, (2) helpfulness of the editorial process, (3) freedom of topic choice, and (4) peer editing as a learning tool. Representative student quotes are found in Box 2.

The theme raised most often in the focus groups was that students felt they had gained valuable writing experience and were more confident in their writing abilities. This result validates this approach to graduate student professional development, as self-confidence in writing abilities has been shown to positively correlate with actual writing performance.^{37,38}

Our focus group results also show that students felt more confident in their ability to "turn off the [scientific] journal-writing voice" and communicate in particular to general audiences. We assert that experience writing on technical topics in a narrative fashion using plain language will poise students to more effectively communicate a variety of technical topics, not just those in their blog posts, to diverse audiences in the future.

We designed the editorial workflow with student concerns over lack of ideas, experience, and time in mind. We were therefore pleased to discover that students reported that the editing and peer-editing processes helped them successfully write their blog posts, even if they had never blogged before (Box 2).

We established broad content and audience guidelines to make the writing experience positive for student bloggers and to ensure maximum overlap between blog creation and students' many other obligations. Consequently, we were pleased that students described freedom of choice of blog post topics as a critical aspect of their positive experience (Box 2).

Students' social networking experiences provided additional unexpected benefits. One student, after sharing blog posts on Facebook, reported: "I've had a few interactions with

Box 2. Main Topic Results and Quotes from Focus Groups*Valuable Writing Experience:*

"It has helped me turn off the journal-writing voice and turn on a different voice."

"I feel more confident."

Editorial Process Helped:

"The editorial process was really helpful, because initially I had no clue what I was doing."

"Talking things through with [the editor] really helps you get your ideas out, and you can actually write a blog even if you've never done it before."

Peer-Editing as a Learning Tool:

"Being a peer editor has been a lot of work but I would say I have definitely learned to communicate science a lot better."

"Being able to edit someone else's writing gives you a lot of insight into the whole process for yourself."

Freedom of Topic Choice:

"I was [excited] because there was less control over what I chose to write about...so it allowed me to use a little more of my own creativity."

"I like the fact that we have freedom as to what to blog about and we can basically pick the topic we want to explore."

professionals that I went to undergrad with who are not in the field and who are interested in learning more about what we are doing." Another student reported having "eye-opening" interactions on Facebook in which (s)he realized many of the friends that (s)he assumed had no interest in science in fact were interested by the blog posts. Finally, a middle school science teacher discovered the blog via a Facebook post of a Center-affiliated student. This connection led to a collaboration in which Center-affiliated scientists responded to questions from eighth grade students. This interaction occurred over the course of a week in the comments section of a blog post.

■ PERCEPTION OF STUDENT WORK BY RESEARCH MENTORS

After 16 months of blogging, we conducted a survey of the graduate students' research mentors. All the mentors agreed or strongly agreed with the following statements (for detailed results see the Supporting Information).

- My student's blog posts are of high quality
- The blog positively contributes to my student's education
- Writing for the blog is worth my student's time
- Writing for the blog gives my student valuable experience in communication to the general public

These results mirror students' own positive impressions (see above) of the professional development utility of this approach.

■ CONCLUSIONS

We have presented the design, implementation, and assessment of a blog designed around the research goals of an interdisciplinary research center. One of the primary goals of this blogging effort was to enhance the written communication

skills of Center-affiliated students. Focus group and survey data reveal that this goal was achieved. Students described feeling more confident in their ability to write blog posts, an indicator that correlates positively with actual gains in writing skill.^{37,38} Students' research mentors were supportive of their students participating in this project. Assessment data highlighted important design aspects of the blog post development process, including the participation of an editor and flexible content and audience guidelines.

■ BRIEF GUIDELINES FOR REPLICATION

After over 16 months of running this multiauthor blog, we believe the following items have been critical to its continued success. We base these recommendations primarily on the above-described assessment data but also on discussions with others who run multiauthor blogs in academic settings.^{39,40}

- *Sufficient participant motivation*, which can come in the following forms:
 - Leadership from superiors (advisors, professors, teachers, etc.)
 - Opportunity for professional development
 - Opportunity for personal expression
 - Grades (though in our case this was not a graded assignment)
- *Schedule of contributions*
 - Mutually agreed upon and transparent
 - Helps ensure regular blog content production
- *Blog manager*
 - Ideally would also serve as blog editor, if time permits
 - Helps remind participants of upcoming (or past) deadlines
 - Helps participants with technical aspects of blogging software
- *Editorial process*
 - Ideally by an individual with experience writing for general audiences
 - Peer editing is also a powerful method for improving writing quality, though guidance of the peer editors by an experienced writer is helpful
- *Flexible content and audience guidelines*
 - Freedom to use their own voice and choose their own topic are important aspects of participants' positive experiences
- *Social networking promotion*
 - Promotion of the blog via social media led to numerous unexpected benefits to the participants

We hope the guidelines above are useful for others who are interested in replicating this model in related settings such as research groups and academic departments.

■ ASSOCIATED CONTENT**§ Supporting Information**

Initial student survey forms and research mentor survey forms along with summaries of the Likert response data. This material is available via the Internet at <http://pubs.acs.org>.

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Notes

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