EFFECTIVENESS OF AND LESSONS LEARNED FROM AN ONLINE SCIENCE COMMUNICATION (SCICOMM) PROGRAM FOR GRADUATE STUDENTS AND POST-DOCTORAL FELLOWS

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Abstract

Despite clear mandates from funding bodies and other institutions encouraging researchers to engage in science communication and outreach, formal opportunities for science communication training are rare and/or piecemeal in most academic science departments. We designed, facilitated, and evaluated an intensive online science writing program for graduate students and post-doctoral fellows. The program blended practical exercises such as writing and peer-editing blog articles with biweekly workshop sessions lead by experts in science communication. Pre- and post-program surveys revealed considerable advancement in trainees' self-assessed knowledge, skills, and confidence in science communication, particularly science writing, blogging, and journalism, with completion of the program. We also reflect upon the overall process of the program, including the challenges of building community and maintaining engagement in an online environment. Online intensive training programs, such as the one piloted here, may be a viable and accessible model for the teaching and learning of science communication skills.
Keywords: science writing, higher education, workshop, blogging, accessibility

Résumé

Bien que ce soit souvent le mandat de nombreuses agences et institutions que les scientifiques s'impliquent régulièrement dans des activités de la diffusion scientifique pour render leur science accessible et intéressante auprès d'un vaste publique, les opportunités d'acquérir ces compétences de communication sont rares et/ou fragmentaires dans les départements scientifiques universitaires. Alors, nous avons developés et évalués un cours en ligne axé sur la rédaction scientifique pour les étudiantes et étudiants inscrits aux cycles supérieurs et les stagiaires postdoctorales et postdoctoraux. Ce programme consiste des exercices pratiques, tels que des exercices d'écriture et de la révision par les pairs des articles de blogue, ainsi que des ateliers bimensuels facilité par des experts en communication scientifique. D'après des sondages menées avant et après le cours, nous avons observés une amélioration

de l'estime de soi des étudiants et leurs compétences en les matières de communication scientifique, en particulier en la rédaction scientifique, en blogue et en journalisme, Nous réfléchissons sur l'intégralité du programme, et les obstacles en la création d'une communauté et au maintien de l'engagement dans un environnement en ligne. Les programmes de formation intensive en ligne, comme celui-ci ont un grand potentiel pour devenir des modèles viables et accessibles d'enseignement pour l'apprentissage des compétences en communication scientifique.
Mots-clés : rédaction scientifique, enseignement supérieur, atelier, blog, accessibilité

INTRODUCTION

Scientific evidence is one type of information that people use to make decisions that collectively impact society (Lederman et al., 2024); therefore, translating research findings into actionable and impactful knowledge influences political and social landscapes. At the same time, current levels of mistrust in science are high and scientific literacy is poor (Kennedy & Tyson, 2023; Lederman et al., 2024), highlighting the need for effective science communication and science education efforts. Moreover, scientific funding bodies, many of which are partially or completely funded by the public, increasingly recognize the importance of science communication by opening additional funding opportunities, embedding science communication and outreach plans into research grant competitions, or other mechanisms.

Despite abundant social, economic, and moral imperatives for effective and high-quality communication between experts and non-experts, scientists receive little formal training in science communication, outreach, or related skills. Formal science communication training opportunities are often unavailable to scientists (Greer et al., 2018). When opportunities are present, they are typically limited to comparatively straightforward technical communication skills such as removing jargon as opposed to strategic thinking (Dudo et al., 2021), or focused on expert-to-expert communication between scientists ("scien*tific* communication"; Bankston & McDowell Gary, 2018). This training gap has real consequences for science communication and outreach efforts, as scientists frequently cite lack of training and lack of confidence in their science communication skills as barriers to their participation in public-facing activities (Brownell et al., 2013; Hundey et al., 2016; Poliakoff & Webb, 2007; Trench & Miller, 2012).

Intensifying the general lack of access to professional development in science communication is the dynamics of unequal power and privilege amongst scientists, science communicators, and others in the space. Science communication is a diverse and interdisciplinary field with strong and explicit connections to science outreach, an area of practice that, by definition, centres historically underrepresented communities in science. While science communication is often viewed as more inclusive of diverse identities than traditional academic science spaces (Bennett et al., 2024), it nevertheless struggles with many of the same inequities, as many science communicators are also academics, leading to overlapping processes, participants, and spaces. Recent efforts toward the broader adoption of inclusive science communication practices (Alderfer et al., 2023; Canfield & Menezes, 2020; Canfield et al., 2020; Vickery et al., 2023) include emphasizing the need for science communicators to centre equity in the framing of their communications (Polk & Diver, 2020) as well as the uptake of anti-racist (Callwood et al., 2022) and feminist (Lewenstein, 2019) approaches.

The current landscape of science communication training opportunities available to scientists and other experts includes self-directed learning from available literature and websites, short workshops, and intensive formal courses offered by professional societies, institutions, and universities. Within this disjointed patchwork remains extensive space and opportunity to develop effective and, ideally, systematic science communication training programs. In designing these potential programs, it is worth thinking about who is the appropriate target audience for science communication training (e.g., trainees vs. established researchers; Bray et al., 2012; Mercer-Mapstone & Kuchel, 2017), whether specific science communication skills and activities should be formally included as part of the curriculum for graduate studies and post-doctoral training (Mercer-Mapstone & Kuchel, 2017), and how to measure the overall effectiveness of these efforts across different time scales and outcomes.

The purpose of this study was to examine a science communication pilot initiative involving an intensive, accessible, multiweek online program in science writing and other science communication skills targeted to graduate students and post-doctoral fellows working in STEM at Canadian universities. Here, we describe our program's design and evaluate the success of the program with survey data collected from participants and personal observations. We also discuss the highlights and challenges of the program with the aim of constructively encouraging greater uptake of effective science communication training programs at the graduate level and above in Canada.

METHODS

Unabridged methodological details are available in the supplemental material.

Program Goals

The goals of the Science Writing Program (SWP, referred to as "Science Writing Internship Program" in surveys and program materials) were to (i) educate STEM trainees on how to effectively communicate with non-expert audiences by developing participants' knowledge, practical skills, and confidence in science writing and science journalism; (ii) create a free online resource of good science communication practices; and (iii) build an online community (network) for graduate and post-doctoral fellows. We also sought to (iv) create a program that was equitable, diverse, inclusive, and accessible based upon the principles of universal design (Center for Applied Special Technology, 2024; Meyer et al., 2014).

Recruitment

Each module was led by one workshop leader and/or up to three panelists recruited by the program facilitators (the authors) or the workshop leader after considering potential leaders' topical expertise, availability, and diversity of experience. Workshop leaders were emerging or established science communicators and were a mix of academics and professionals in science communication or adjacent spaces (e.g., publishing, teaching). All workshop leaders had received external recognition for their contributions and had expertise specific to their assigned workshop topic. Workshop leaders designed their session and materials as they saw fit within the parameters provided by the program facilitators.

Any graduate student or post-doctoral fellow (referred to collectively as "trainees") based in Canada and working in a STEM discipline (broadly defined to include health sciences and social sciences) was eligible for the program. Trainees were recruited through an advertising campaign across social media and email as well as informal interactions with facilitators at invited talks, conferences, and elsewhere.

Application Evaluation

Recruitment efforts directed potential participants to an online application form (Material S1) and informed consent form hosted on Qualtrics software through Wilfrid Laurier University. Completed applications received prior to the deadline (N = 121) that met basic eligibility criteria were collaboratively assessed by facilitators based upon applicant's stated interest in science communication including science writing and related subfields (excluding scientific communication, such as grants and manuscripts), how participation in the program would benefit them, and what skills they were interested in developing (Material S1, questions 12 to 14). Following assessment, the facilitators confirmed that the diversity of the selected cohort was reflective of the applicant pool (Material S4), and that any special circumstances shared by applicants were appropriately considered. The final cohort included 25 graduate students and five post-doctoral fellows (with N = 28 consenting to participate in research). Applicants were asked to flag accessibility concerns so that they could be proactively resolved before the program commenced.

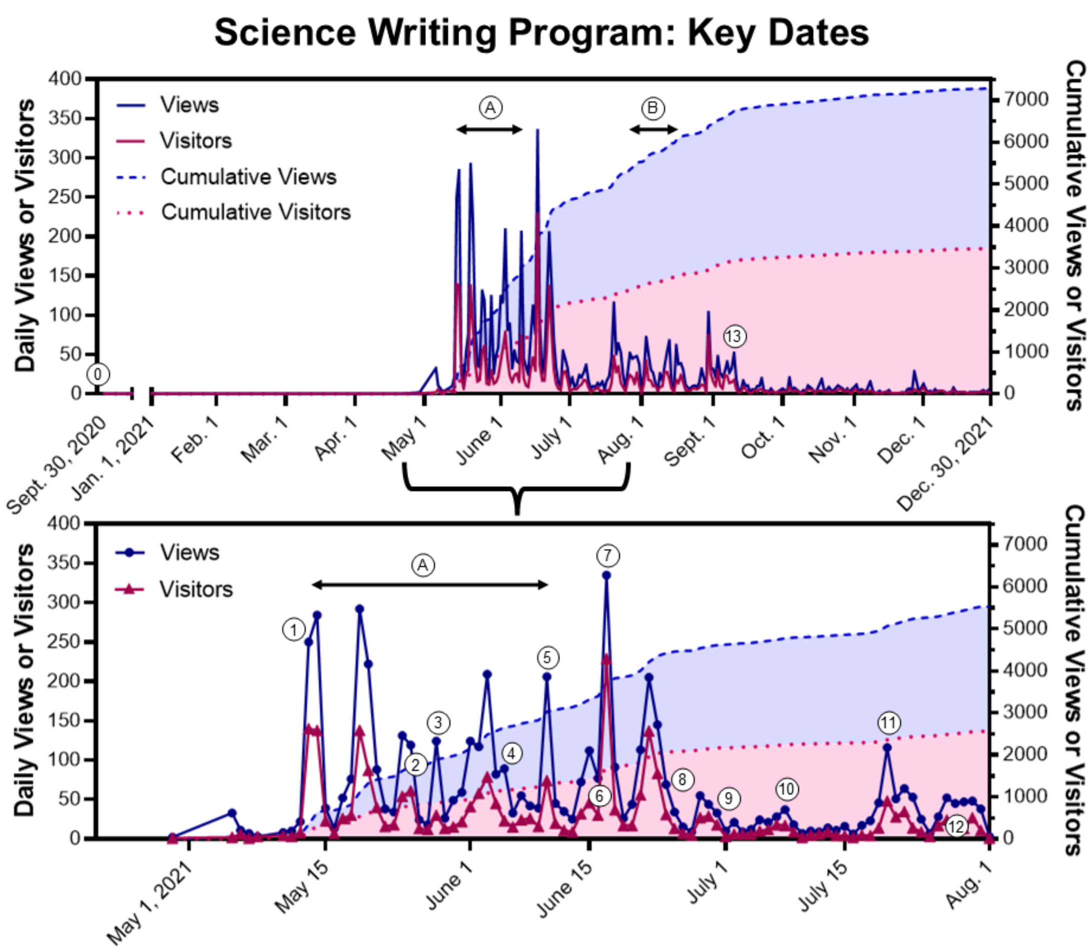
Science Writing Program

Program Format

The program was delivered using the synchronous video communication and messaging software Zoom, which was occasionally supplemented by email and/or a cloud-based Slack group. Each program module (Figure 1) highlighted a different science communication topic with approximately one third of program content specifically targeting science writing, blogging, and/or journalism.

Figure 1

Timeline of the 2021 Science Writing Program



Note. Daily website views and visitors (solid lines) and cumulative views and visitors (shaded regions) are shown as a proxy for overall engagement. Annotated dates: (0) Funding acquisition; (1) Applications open; (2) Application deadline; (3) Participant onboarding; (4) Science Communication 101 module; (5) Introduction to Science Blogging module; (6) Blog Article #1 deadline; (7) EDI in Science Communication panel; (8) Misinformation in the Post-Truth Era module; (9) Pitching, Journalism, and Publishing in the Popular Press module; (10) Careers in Science Communication panel; (11) Article publication begins; (12) Blog Article #2 deadline; (13) Article publication ends. (A) Pre-program survey period; (B) Post-program survey period.

Workshop Sessions (Synchronous)

Workshop leaders used a combination of prepared slides, facilitated discussion, and small group exercises during their two- or three-hour sessions. After each workshop session, materials such as slides, recordings, and transcripts were shared with participants using a password-protected section of the program website.

Blog Articles

Participants wrote two blog articles and edited two articles written by their peers. For Article #1, participants were instructed to write a ~750-word post for a Canadian high school student with a Grade 9 education about their research or a recent peer-reviewed scientific paper. Participants were provided with feedback by facilitators within roughly one week of submission and submitted a revised article for publication on the program website. Common feedback included altering the order of paragraphs to follow popular science/science news–type structure, using a more casual and approachable authorial voice, and limiting the use of technical jargon. Revised articles underwent a round of production editing by a facilitator before being posted on the public section of the program website and shared on social media.

The criteria for Article #2 only specified a “general public” audience. For Article #2 only, participants engaged in peer-editing by providing feedback for two others in the cohort. In a small minority of cases, a program facilitator functioned as a peer editor to ensure all participants received prompt feedback from two sources. Peer-edited and revised articles were published as described for Article #1. Articles were maintained on the program website until April 2023 (except when early removal was requested), and their performance was monitored using analytics built into the website hosting platform.

Transcripts and Notetaking (Asynchronous)

All participants completed assigned notetaking and transcript correction duties for the synchronous sessions. Participants freely choose their session(s) and independently coordinated with others assigned to the same session. Notes and corrected transcripts were uploaded within about one week to the program website.

Program Evaluation

Participants who consented to participate in our study were asked to complete two surveys (Figure 1, Materials S1–S3) with fully optional questions. The pre-program survey (Survey A; Material S2) was attached to the application form and assessed participant’s pre-program (baseline) experience, knowledge, skills, and confidence in science communication and science communication activities. The post-program survey (Survey B; Material S3), focused on participants’ self-assessment of the effect of participation in the program on these characteristics.

RESULTS

Effect of Program on STEM Trainees’ Expertise in Science Communication

Participants’ Prior Knowledge, Expertise, and Training in Science Communication

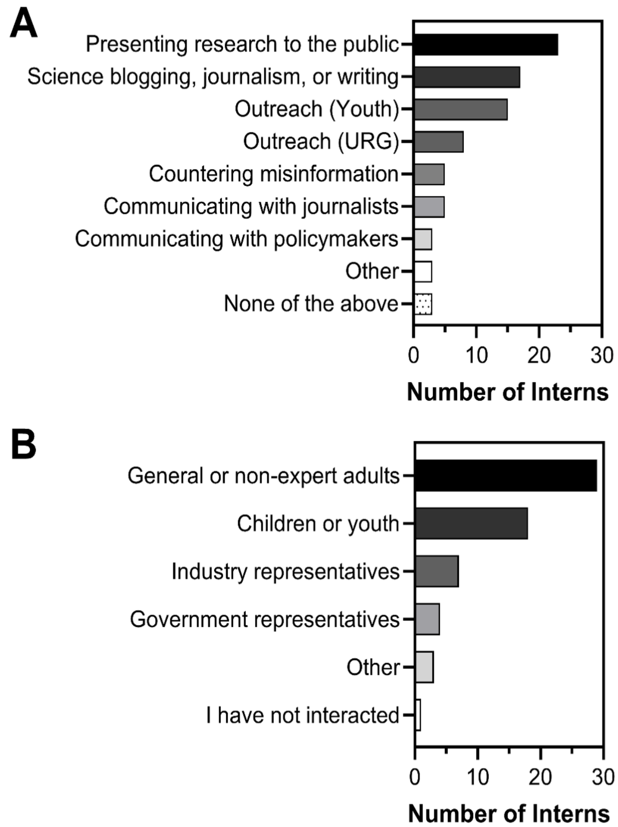
Program participants had limited expertise in science communication upon intake: All participants self-identified as either beginner (N = 15, 52%) or intermediate (N = 14, 48%) science communicators. Most existing expertise was practice-oriented, and participants had little general knowledge of research conducted in the field of science communication (N = 9 had no or “less than beginner” level knowledge, N = 18 had beginner-level knowledge, and N = 2 had intermediate-level knowledge).

Participants were evenly divided between those with formal training in science communication ($N = 15$) and those who had no formal training ($N = 14$). Most participants did not engage in science communication activities as a core component of their degree program or as a requirement of their job ($N = 16$, or 55% vs. $N = 9$, or 31%). A minority of participants indicated that they were "not sure" ($N = 4$, 14%) whether science communication was a part of their degree program or job description, which we interpreted with the aid of supplemental text responses as participants whose duties had *informally* expanded to include some science communication work.

Many participants were involved in extracurricular activities, including supplemental training or volunteer work related to science communication. Most of the participants ($N = 18$, 62%) reported spending at least one hour per week on science communication activities independent of their degree or employment, with some participants ($N = 3$, 10%) spending as much as five to nine hours per week on these activities. Many participants engaged in multiple science communication activities ($N = 28$ participants selected a total of $N = 71$ activities from a pre-determined list, translating into an average of two to three activities per participant). There was a clear preference for activities that are commonly available in a typical university environment such as presentations, science writing, and outreach activities (Figure 2A).

All participants had previously interacted with non-expert adult audiences including friends, family, community members, and social media followers in a science communication context (Figure 2B). Consistent with the cohort's relatively high level of experience in outreach, children or youth were the second most common audience ($N = 17$, 59%), with policy and government ($N = 3$, 10%) and industry-based audiences ($N = 6$, 21%) representing much smaller minorities of previous audience interactions.

Figure 2
Prior Experience in (A) Select Science Communication Activities and (B) Interacting with Specific Audiences



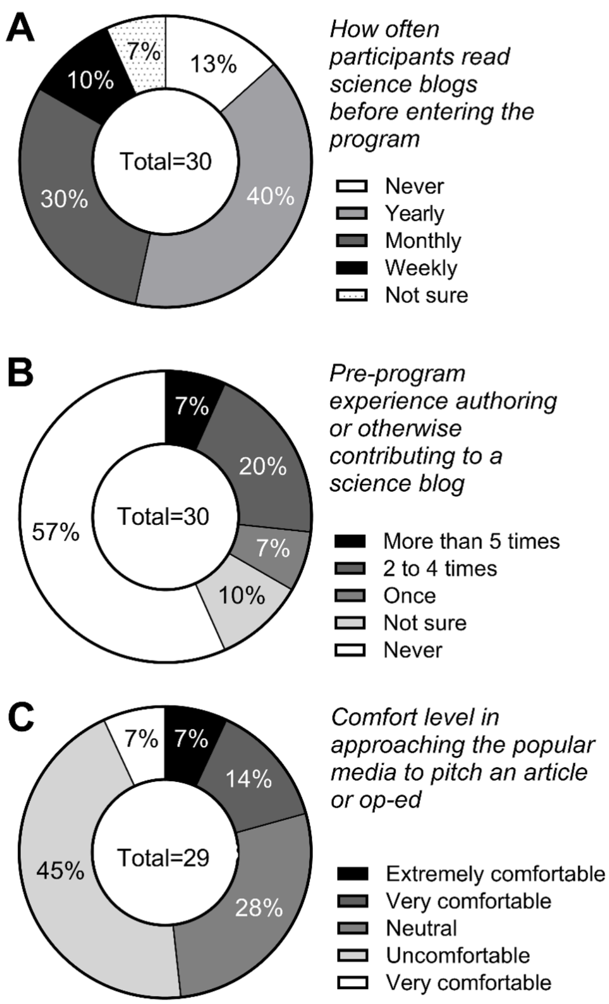
Note. $N = 29$ total respondents. Respondents could select multiple answers for each question.

URG = underrepresented or disadvantaged groups.

Participants' Prior Experience in Science Writing and Related Fields

We also assessed incoming participants' specific experience in science writing, science blogging, science journalism, and related fields (Figure 3). Most participants regularly, albeit infrequently, consumed science blogs as readers (*N* = 23, 80%; Figure 3A). Most participants (*N* = 15, 54%; Figure 3B) had never contributed to a science blog themselves (e.g., as writers, editors, etc.) and felt uncomfortable or very uncomfortable (*N* = 15, 53%; Figure 3C) at the prospect of pitching an article or op-ed to the popular press. Presumably, the participants who were extremely comfortable (*N* = 1) or very comfortable (*N* = 4) with pitching an article were those with more blogging experience, though we are unable to confirm this due to data aggregation.

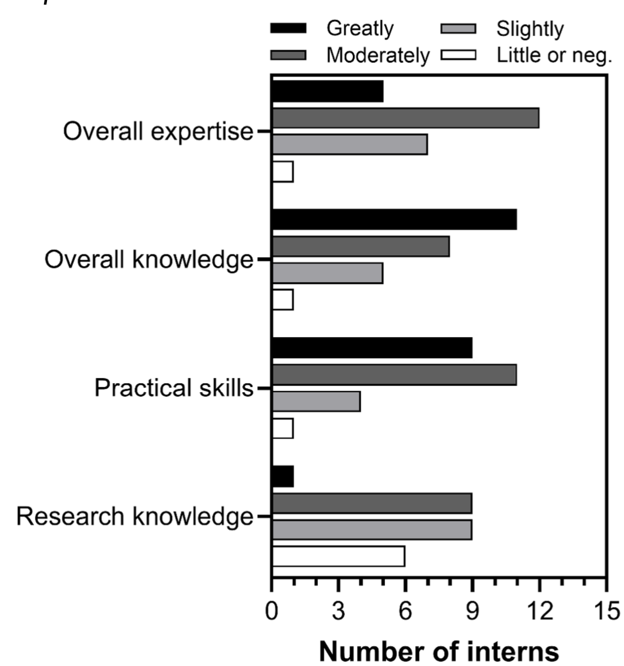
Figure 3
Prior Engagement in Science Writing and Related Activities, Including Consuming (A) and Contributing (B) to Science Blogs as well as Comfort Level in Pitching an Article to the Popular Press (C)



Effect of Program on Participants' Expertise, Knowledge, and Confidence in Science Communication

The SWP had a strong positive effect on participants' self-assessed expertise in science communication, with most participants reporting that participation in the program moderately increased or greatly increased (*N* = 17, 68% of respondents) their overall science communication expertise (Figure 4). This improvement in overall expertise was rooted in near equal improvements in knowledge and practical skills, with 76% (*N* = 19) and 80% (*N* = 20) of participants selecting that the program moderately or greatly increased expertise in these categories, respectively. Participation in the program also moderately or greatly increased knowledge of research conducted in the field of science communication in 40% (*N* = 10) of participants.

Figure 4
Self-Assessed Impact of the Program on Participants' Practical Skills, Knowledge, and Expertise in Science Communication

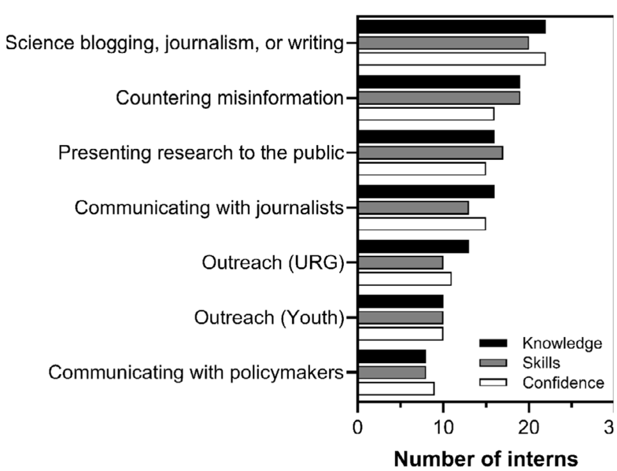


Note. Neg. = negligible.

We asked participants to identify how the program impacted their knowledge, confidence, and skills related to conducting the same list of specific activities that we used to assess their previous experience in science communication in the pre-program survey (Figure 5). Unsurprisingly, ≥80% of participants agreed that the program improved their knowledge, skills, and confidence in science journalism, science blogging, or science writing for the public. There were similar gains for the activity of communicating with journalists (*N* = 18, 75% for knowledge; *N* = 14, 58% for confidence; and *N* = 16, 67% for skills), presumably due to a combination of the "demystifying" effect of learning more about the popular science publication process and interacting with a professional science editor as a part of the program. Interestingly, a sizeable proportion of the cohort reported improvements in knowledge, confidence, and skills in activities that were rarely or not discussed in the program, such as communicating with policy makers and outreach to youth.

Figure 5

Number of Interns Who Self-Assessed that Completion of the Science Writing Program Improved Their Knowledge, Skills, and/or Confidence in Engaging in Science Communication Activities

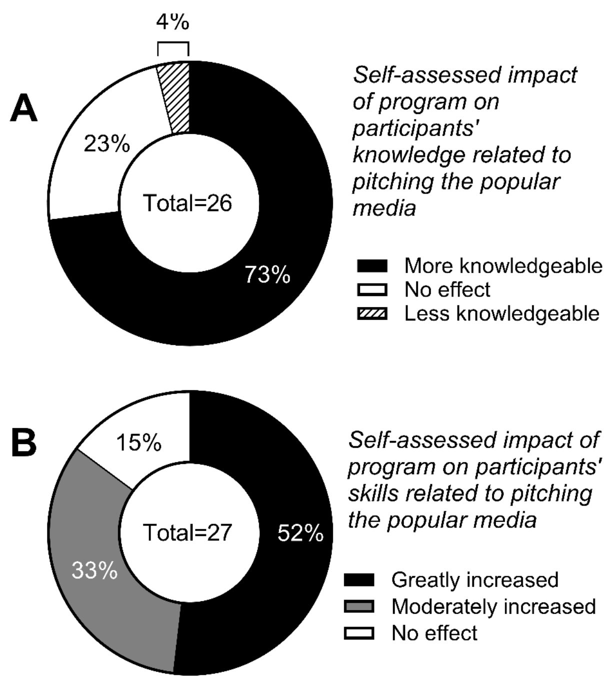


Note. URG = underrepresented or disadvantaged groups.

We also specifically assessed how the program impacted the participants' self-assessed knowledge, skills, and comfort level in pitching a media outlet, a critical activity for writing-based science communication. Most participants (*N* = 21, 81%) reported that they were now much more likely to pitch an article or op-ed for publication in the popular press following the completion of the program, likely supported by improvements in their self-assessed knowledge and practical skills related to the popular media pitching process (Figure 6).

Figure 6

Participants' Self-Assessment of How the Science Writing Program Impacted Their Knowledge (A) and Skills (B) Related to Pitching an Article to the Popular Media



Participation in Science Communication Activities Within One Month of Program Completion

As a longer-term assessment of program performance and success, we asked participants to describe their engagement in science communication activities in the time between completing the formal program (July 8, 2021) and completing the post-program survey (August 16, 2021). As with the pre-program survey, the most popular science communication activities were science journalism, science blogging, or science writing ($N = 10$, 71%) and presenting research to the public ($N = 6$, 43% of respondents).

Most participants reported reading slightly ($N = 11$, 44%) or substantially ($N = 5$, 20%) more science blog–type articles compared to their pre-program survey. A few participants shared that they had already published an article in a popular media outlet or that they were at least in the process of pitching to an outlet. Even participants who had not yet approached an outlet expressed that they were more likely to approach a media outlet ($N = 17$, 74%). Taken together, the SWP generally increased participants' engagement in all aspects of science writing and journalism, including being a reader, source, and writer, and this was detected one month after the end of the program.

Aside from science writing, participants also engaged in science communication activities on social media, networking with journalism students at their institution, attending science communication conferences, and connecting with resources such as training programs or courses. Most participants ($N = 18$, 72%) also noted that their completion of the program made them more likely to pursue formal training in science communication in the future.

Use of Online Resources Produced During Program

A second goal of our program was to collate workshop-associated materials into a free online resource of good science communication practice. Resources created throughout the program, including video and transcripts of workshop sessions, summary notes provided by participants, and completed blog posts, were collected and hosted on the main program website. Access to some resources was restricted to program participants only by using a password-protected webpage or unlisted video hosting.

We quantified the use of the resources between the program start date (May 1, 2021) and the end of the year (December 31, 2021; Figure 1). Session recordings garnered 124 total views, with an average of 21 ± 6 views per video (Table 1). It is worth emphasizing that these videos were only accessible to ~32 people and that most views were repeat viewings due to high attendance rates for "live" sessions. Therefore, even the lowest performing video ($N = 7$ views) was accessed by up to 24% of all participants and at least one video ("Science Blogging") was viewed repeatedly by several participants. Given the large discrepancies between the total length of the videos and their average view duration (typically five minutes or less) as well as the excellent attendance to the synchronous sections, we conclude that most participants used the recordings strategically, finding specific sections that they were interested in and rewatching only those sections.

We quantified traffic to pages that hosted resource files as a proxy for interest in and use of transcript and notes files (Table 2). Resource page access was considerable, with the number of unique visitors exceeding the number of participants for most of the duration of the program. Presumably, social media posts on Twitter (now X) advertising public components of workshop sessions and/or promoting participant-contributed articles may have motivated people otherwise unaffiliated with the program to visit these pages.

We quantified the performance of all published participant-contributed articles. Each article was promoted on social media by program facilitators, and participants were encouraged to share and further publicize their work. Article views ranged from 118 views with 80 unique visitors to five views from four unique visitors. Articles received an average of 47 ± 9 views from 34 ± 7 unique visitors, indicating that they generally succeeded in reaching at least some audience beyond participants of the program (Table S1).

Table 1
Session Recording View Statistics on YouTube

Module	Views	Video length	Average view duration	Average percentage of video viewed
Science Communication 101	28	00:57:40	00:04:34	7.9%
Introduction to Science Blogging	43	00:49:52	00:05:05	10.2%
EDI in Science Communication	14	00:55:43	00:21:54	39.3%
Misinformation in the Post-Truth Era	7	00:55:52	N/a	N/a
Pitching, Journalism, and Publishing in the Popular Press	8	00:54:50	N/a	N/a
Careers in Science Communication	24	01:27:48	00:03:48	4.3%
Mean ± sem	21 ± 6	1:00:18 ± 5:36	8:50 ± 4:22	15.4% ± 8.1

Note. N/a = not enough information/views for built-in analytics to be compiled. Times are provided in hh:mm:ss format.

Table 2
Monthly Traffic to Website Pages that Hosted Program Resources Files

Month	Page views	Unique visitors	Total site sessions	Bounce rate (%)	Average time on page (min:sec)
May	98	59	77	100	07:28
June	70	47	62	100	06:14
July	69	32	55	43	05:47
August	22	13	13	29	03:54
September	15	10	11	0	03:26
October	12	7	7	0	03:26
November	3	3	3	0	02:32
December	1	1	1	0	01:53

Note. N/a = not enough information/views for built-in analytics to be compiled.

Perhaps unsurprising for the summer of 2021, some of the most popular articles covered COVID-19, viruses, or the pandemic (e.g., articles #17, #22, #29; Table S1). Articles with custom illustrations or infographics provided by the author also performed well (#1, #29). Other popular articles covered a diversity of topics, including the material science of soap films (#2), the importance of fundamental research (#3), esophageal stem cells (#5), the role of bacteria in food production (#11), and phosphate metabolism in plants (#18).

Program Accessibility and Barriers to Science Communication Training

Whenever possible, we incorporated recommendations for universal design for learning (Center for Applied Special Technology, 2024; Meyer et al., 2014) into program design and delivery. This included the online modality of the program, which enabled embedded accessibility tools such as live closed captioning and transcription scripts. With the presenters' permission, we also recorded modules so that trainees could rewatch the videos at their convenience and provided a 15-minute break in the middle of the synchronous sessions.

During onboarding, we queried participants for any accessibility needs (n.b., participants were explicitly informed that they were not expected to disclose their disability). None of our 28 participants affirmed "yes" that they required accommodations, though overall, 18% (N = 5) noted that they "maybe" required accommodations, including live transcription and/or closed captioning (N = 2), breaks every 30 minutes (N = 1), and additional time to complete some assignments (N = 1). All accommodation requests were implemented during the program.

As 27% of Canadians aged 15 years or older have at least one disability (Statistics Canada, 2023), we expected ~8 persons with a disability to be present in the cohort (n.b., we use identity-first language to recognize disability as an identity and cultural group. We acknowledge that there are different perspectives on using identity-first or person-first language). We suspect that there are multiple non-exclusive explanations for the lack of affirmative disclosure of disability in the cohort, including that those in our cohort do not identify as being disabled (consciously, or unconsciously through masking), that participants may have been reluctant to "out themselves" due to associated stigmas and negative stereotypes (Kendall, 2016; Nieminen & Eaton, 2024), that trainees might have been unsure of the safety and/or effectiveness of requesting accommodations, that participants might have been unsure of what accommodations to request or what accommodations could be provided, or that the participant cohort was not truly reflective of the general Canadian population.

With regard to the final possibility, graduate students and post-doctoral fellows tend to have a lower rate of disability compared to undergraduate students or even the general population (Tamjeed et al., 2021; Toutain, 2019; Wells & Kommers, 2022). Due to the highly variable nature of research-based/thesis-based science programs (including power dynamics between graduate students and their research advisors/departments) as well as the greater emphasis placed on undergraduate students by most accessible learning offices, graduate students with disabilities may be unaware of or underserved by services typically available to them on campus (Tamjeed et al., 2021), and therefore generally reluctant to ask for or pursue accommodations.

We also asked participants what, if any, potential barriers from a pre-determined list had impacted their ability to complete training in science communication. The primary barrier identified was lack of resources such as funding or time. Additional barriers included ineligibility for training programs (N = 6) as well as concern that supervisors or peers would react negatively to their interest in science communication work (N = 6), a response that reflects the personal and anecdotal experiences of the program facilitators. Two participants also identified that a lack of inclusivity or accessibility in training programs had been a barrier to their participation.

To further pursue this topic, we asked trainees to describe any current or potential barriers to their formal science communication training. Coding of the participants' responses (N = 13) gave a clear impression from science research culture that science communication is not a valid part of research or good use of trainees' effort or time. More specifically, 54% of respondents (N = 7) cited time limitations as a barrier. One response summarizes this view: "I would worry that my current degree would not leave me with enough time to pursue science communication to the extent which I would like to." Somewhat related, four trainees stated that a barrier was the pressure to focus on research and/or the perception that their research supervisor would not be supportive of science communication training. An exemplary response from one participant is that "I would like to pursue more science communication activities, but I worry that my lab supervisor wouldn't like it because of the potential to take away from research time." Five trainees (38%) also stated that it was difficult to find science communication training opportunities and that these opportunities were not advertised in spaces where they had access, with two trainees (15%) indicating that knowledge about science communication careers and possibilities was a barrier.

Three (23%) trainees stated that cost or lack of funding was a barrier to their participation in science communication training. The requirement to pay for training out of their own pockets was a concern, and trainees generally displayed a low level of knowledge about whether their institution provided awards, scholarships, grants, or other funding for science communication projects, with 62% of respondents noting that they were "not sure" if those opportunities existed ($N = 4$ answered "no" and $N = 7$ answered "yes"). Of the minority of respondents who knew about funding opportunities that were available, four (57%) had successfully applied for funding, suggesting that trainees were fairly likely to succeed in obtaining science communication funding from their institution once they knew that it was available. When asked about science communication opportunities beyond their institution, such as through scientific societies or private businesses, trainees displayed an even greater lack of knowledge, with 79% reporting they were "not sure" if these opportunities existed ($N = 3$ answered they were not aware of any opportunities). Very few participants had seriously investigated pursuing these streams of funding (and none had formally applied), with three noting they were eligible but had not applied and one noting that they were not eligible for them.

DISCUSSION

Science Communication Training Available to STEM Trainees in Canada

The SWP cohort is a geographically diverse and multidisciplinary group of trainees unified by an interest in science communication, and therefore provides an informative, if ad hoc, snapshot of the landscape of science communication training in Canadian STEM programs. They demonstrate that science communication training or practice is rare amongst graduate students and post-doctoral fellows, a trend that has been widely observed in similar cohorts elsewhere (Brownell et al., 2013; Hundey et al., 2016; Kuehne et al., 2014).

Of the science communication training or experience that is available through STEM programs, survey responses suggest that it is restricted to forms of science communication common in a university setting such as presentations. This mirrors results of an earlier survey of recent and pending PhD graduates in aquatic sciences, which found that oral science communication was the preferred activity in terms of both participant-rated importance and frequency of conducting the activity (Hundey et al., 2016). Presentations are a logical entry point for broader participation in science communication, as scientists do presentations in other contexts with their peers, and so they may be more easily "accepted" as a worthwhile endeavour compared to other types of science communication (note that several trainees identified the opinions of their peers or supervisors as a barrier to their pursuit of science communication).

To account for deficiencies in science communication opportunities in their programs, trainees often resort to an "ad hoc" approach to science communication training, typically developing their skills through informal means such as reading articles, mentoring by "scicomm-friendly" advisors, personal experimentation (Crone et al., 2011), or seeking out programs like the SWP. Overall, we view the general lack of opportunity for science communication training through STEM programs as a major oversight in the training of future scientists.

Self-Assessment to Measure Efficacy of Training

Growing recognition that scientists should at least be competent science communicators (Brownell et al., 2013; Rubega et al., 2021) has motivated the creation of several science communication training programs for researchers (Baram-Tsabari & Lewenstein, 2017; Kuehne et al., 2014; Rodgers et al., 2018; Rubega et al., 2021). As it stands, every program is unique (e.g., see Kuehne et al., 2014 for a non-exhaustive list of example programs), and there is no clear consensus for best practices in designing and assessing them (Baram-Tsabari & Lewenstein, 2017; Rodgers et al., 2018). Not all science communication programs include specific evaluation of their efficacy, and many of those that do rely upon internal metrics such as student grades (Vickery et al., 2023). Another evaluation method is participant self-assessment through surveys or similar tools (Rodgers et al., 2020), which has its own limitations (Cohen et al., 2017). When queried in this way, as we and others have demonstrated, participants in training programs typically report increased confidence in their ability to perform a range of science communication and outreach activities (Chamely-Wiik et al., 2019; Heath et al., 2014; O'Keeffe & Bain, 2018).

Occasionally (Baram-Tsabari & Lewenstein, 2017; Rubega et al., 2021), program evaluators will attempt to validate self-reported improvements in science communication skills, as self-assessments are not always reliable (Dunning et al., 2004; Falchikov & Boud, 1989; Hansford & Hattie, 1982). By employing a triangulated framework of evaluators (graduate student trainees, faculty trainers, and "ordinary citizens") Rodgers et al. (2018) showed that trainees' perceived improvements in science communication skills and knowledge *did* translate to the performance of an oral presentation developed over the course of the program. Other investigations using standardized rubrics to score oral presentation skills have also found agreement between perceived and demonstrated improvements in science communication skills (Chamely-Wiik et al., 2019; Willoughby et al., 2024). In contrast, a recent and rigorously controlled, semester-long experiment showed that science communication training has virtually *no effect* on the graduate students' clarity, engagement, or credibility (rated by an audience of undergraduate students) and that presenters consistently overestimated their self-efficacy, highlighting the perils of relying on self-assessment of science communication skills (Rubega et al., 2021). Future iterations of the SWP or similar science writing programs would do well to independently assess markers of communication skills such as blog article post quality and clarity, perhaps through "test readers" or even quantitative metrics of readability (e.g., Flesch–Kincaid readability tests).

Challenges of Online Community Building

Both students and faculty agree that building community is important in learning and that it is more difficult to build community online than with traditional (in-person) modalities (Vesely et al., 2007). Community building, connections, and resource sharing (including training) are key parts of the practice of science communication, particularly for inclusive science communication that centres equity, inclusion, and marginalized perspectives in science communication (Canfield & Menezes, 2020; Menezes et al., 2022). Communities and strong networks have numerous benefits, including facilitating collaborative approaches by removing silos (Menezes et al., 2022), and resisting the hierarchical and exclusionary academic culture that many science communicators (especially those embedded in institutions, such as our participants) contend with when participating in this rapidly expanding and interdisciplinary field.

We attempted to build a sense of community in several ways, including: (i) encouraging participants to turn their cameras on to promote engagement and familiarity; (ii) use of the chat feature to encourage interaction between trainees, facilitators, and speakers; (iii) use of active learning exercises that required group work; and (iv) maintaining a Slack group for interaction outside of scheduled hours. Several of these strategies correspond to published guidelines for building online communities, such as combining asynchronous and synchronous technologies and assigning students tasks that require collaboration (Pacansky-Brock, 2012; Yuan & Kim, 2014).

Despite participants having easy access to each other through the Slack group and embedded program-related "icebreakers" that could serve to seed a peer relationship (e.g., coordinating notetaking and transcription work, peer-editing), we found little evidence for the development of a high-quality network within the cohort (at least within the confines of the official channels created by SWP), a finding that reflects previous work demonstrating that while graduate students desired online collaboration, they find it difficult to execute (Trespalacios & Uribe-Flórez, 2020).

The specific context of the SWP occurring in the spring and summer of 2021, when many Canadian universities were under emergency lockdown in response to the COVID-19 pandemic, adds additional layers to this consideration. For example, the SWP may have had an outsized role for social engagement for participants due to limited in-person avenues for interaction during the programming period. Conversely, SWP may have contributed to an overriding sense of "Zoom fatigue" as one of many academic functions held online during the period.

Given the value of connection and community in science communication spaces, future iterations of the program should prioritize it by placing greater emphasis on the community-building aspect through greater instructor modelling of pro-community behaviours (Vesely et al., 2007), alterations in session programming (e.g., asking participants to introduce themselves during an introductory meet-and-greet Zoom session; Trespalacios & Uribe-Flórez, 2020), and/or additional opportunities for interaction (e.g., optional co-working events) as a means of increasing connectedness in our cohort.

CONCLUSIONS

Demand for our workshop was high, and participants remained engaged throughout the program. Self-assessment by trainees indicated that they found the training useful and effective when it came to their knowledge, confidence, and skills in science communication, especially in improving science journalism, blogging, and writing skills. The survey also identified several barriers to science communication training including time constraints, availability of training opportunities, and financial costs. We found that online training offered the advantages of allowing participation by trainees in different geographical areas and at different institutions, and generally met the needs of participants with disabilities, though it was difficult to build a sense of community using this modality of delivery. Online science communication workshops are a viable model for the teaching and learning of science communication skills in STEM trainees.

ETHICS STATEMENT

This study was approved by Wilfrid Laurier University's Research Ethic Board (REB #6836) and conforms to guidelines set by The Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2).

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SUPPLEMENTAL MATERIALS

1. Material S1: Application form for the Science Writing Program (SWP).
2. Material S2: Final text of the pre-program survey (Survey A).
3. Material S3: Final text of the post-program survey (Survey B).
4. Material S4: Unabridged description of study methods.
5. Table S1: Science Writing Program blog post analytics.

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