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ComSciConCAN and the Positive Impacts on STEM Graduate Students' Confidence and Sense of Belonging

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SUMMARY

Science Communication (SciComm) has many implications for scientists and the larger community, including its role in public policy formation. Though a growing field, undergraduate and graduate level SciComm training programs currently exist worldwide, and the impacts of many have been previously explored. Two noted benefits of such programs include improvement in SciComm confidence and sense of belonging. ComSciConCAN, a Canadian version of the U.S. ComSciCon workshops, is a graduate-level SciComm conference, aiming to provide STEM students with an opportunity to improve their SciComm skills. We are not aware of any previous studies that analyzed the impacts of this conference, which encouraged us to initiate this study. We asked ComSciConCAN-2021 participants to complete surveys before and after the workshop. According to survey responses, the conference significantly enhanced the participants' confidence in communicating with other scientists and lay audiences. Additionally, the participants' perceptions of the conference revealed benefits for their sense of belonging and commitment to the scientific community.

ABSTRACT

Although Science Communication (SciComm) is a growing field, there currently exist many undergraduate-and graduate-level SciComm training programs worldwide. Two noted benefits of such programs are improvement in SciComm confidence and sense of belonging. ComSciConCAN is a graduate level SciComm conference; no studies have previously looked into the impacts of this conference, which encouraged us to initiate this study.

Purpose: To explore the impacts of ComSciConCAN on the participants' confidence in communicating with other scientists and the general public as well as their sense of belonging in current STEM programs and SciComm activities.

Methods: ComSciConCAN-2021 participants were asked to complete surveys before and after the workshop. Data analysis was done using Microsoft Excel, and unpaired t-test statistical analyses were conducted using Graphpad.

Results: With regards to confidence, significant differences ($p < 0.05$) were observed in the mean levels reported for all three cases pre-versus-post conference. Regarding sense of belonging, 65% and 83% of the participants reported at least "somewhat agreeing" that the workshops will help improve this in their current STEM program and SciComm activities, respectively.

Conclusion: The conference had a positive impact on the participants' SciComm confidence and senses of belonging.

Keywords: Male, mental health, progressive media, conservative media, written news media, stigma

INTRODUCTION

1.1 What is Science Communication (SciComm) and Why is it Important?

Science Communication (SciComm) is the practice of disseminating scientific knowledge to different audiences using appropriate strategies and media. Past research has revealed substantial deficits in the public's understanding of science and ineffective SciComm has been well identified as one of the main factors contributing to this issue.[1]

1.2 Implications of SciComm within the Community

The dangers of ineffective SciComm have been best highlighted throughout the COVID-19 pandemic. Concurrent with the pandemic, the world has experienced the rise of "infodemics" surrounding the virus, which refer to the presence of an overwhelming amount of information, including false or misleading information.[2] This has left various communities dealing with differing degrees of mistrust in science.[2] One instance includes the narrative portraying COVID-19 vaccines as a means of implanting microchips in human bodies for the purpose of those in authority, such as Bill Gates, to obtain surveillance over the global population.[3] A similar false belief has also been circulating regarding the messenger ribonucleic acid (mRNA) vaccine technology, which was used to develop the Pfizer/BioNTech and Moderna COVID-19 vaccines.[4] Some have stated that this technology is brand-new, unconventional, and thus, cannot be trusted.[4] Although it is true that this is a new technology used for vaccine development, research in the field has been advancing for almost two decades.[5] In addition, safety and efficacy trials for these vaccines have shown high efficacy rates of 94-95% after the delivery of two doses.[6]

Such false views and conspiracy theories can weaken the public's trust in science. In a study done in the United States (U.S.), researchers found that belief in false narratives related to COVID-19 correlated with significantly lower trust in science.[7] This result is followed by a range of real-life consequences with a negative impact on health behaviors, such as increased vaccine hesitancy, thus not only undermining the work of scientists but also harming the health of the community.[8]

During this time, it has been more important than ever for scientists to be able to both get their messages across to various audiences effectively and distinguish themselves from non-credible sources of information. This is where SciComm training programs step in, providing scientists with an opportunity to build on their skills in communicating science with non-expert audiences.[9]

The implications of SciComm and SciComm training programs have a history far beyond the current pandemic. The most evident instance involves the topic of climate change and its origins. Though it has been scientifically determined that the increased pace of global climate change over the past few decades is unequivocally attributed to human activity, the public awareness around this topic does not live up to its expectations.[10] A U.S. study in 2016 revealed that less than half of adults surveyed had views in line with those of scientists, while 31% reported believing in natural causes to be the driving force for climate change, and 20% indicated not believing in climate change at all.[11] Further, research has shown non-scientific grounds for beliefs about climate change. Specifically, a study by the Pew Research Centre uncovered a political basis: while 61% of Democrats considered climate change a major threat in 2009 and 88% in 2020, only 25% of Republicans did so in 2009 and 31% in 2020.[12]

The aforementioned research demonstrates that the path of science translation from scientists to the general public is already one of nonlinear nature with various confounds such as political and economic agenda potentially blurring the scientists' messages. The problem is only compounded in the presence of ineffective SciComm by scientists themselves. Time and time again, it has been suggested that inappropriate SciComm may indeed be the root cause of this knowledge gap between the experts and the larger community.[13,14,15] Considering that non-expert understanding of science is required for the public to support policy changes and governmental action, the broader implication of SciComm can be recognized. This once again highlights the importance of experts' ability to effectively communicate their findings with lay audiences and to differentiate themselves from biased sources of information.

1.3 Implications of SciComm within the Community

With more studies shedding light on the impacts of SciComm in the broader community, knowledge translation to non-expert audiences is now considered a duty of the scientist.[16] Indeed, the term *civic scientist* was coined in the late 1990's to emphasize the importance of communicating science as a civic duty for science experts.[16] Previously, this was primarily the responsibility of teachers, trained science writers and journalists, and outreach coordinators.[17] However, after recognizing that scientists themselves are the most reliable source of scientific information, they are now expected to contribute to the public understanding of science.[18,19]

This expectation from scientists has been followed by research funding institutions mandating or encouraging researchers to possess SciComm skills and communicate their research with the larger community. As early as 1995, five of the United Kingdom Scientific Research Councils, involved in physical and life sciences as well as engineering, suggested that all researchers receiving grants from public funds should be responsible for explaining to the general public what the grant is enabling, or has enabled them to do, what the implications of their work are, and how it fits into the big picture.[20] For instance, the Biotechnology and

Biological Sciences Research Council (BBSRC) established a requirement for all funded researchers to allocate a portion of their time to activities aiming to promote public understanding of science.[20]

A study reviewing the policies and guidelines of science research funding bodies in Europe, North and South America, Asia and Oceania , and Africa has also discovered that many funding institutions now require or encourage scientists to share their findings with non-scientific audiences through dialogue.[21] As an example, the United States National Institutes of Health (NIH) has established a policy which requires public access to researchers' findings, through the *PubMed Central* website, within 12 months of publication in an academic journal.[21] Similarly, the United States National Science Foundation (NSF) requires scientists applying for research grants to outline their project's "broader impacts", which may include elements like enhancing public scientific literacy and engaging the public with science and technology.[22]

In Canada, although not a funding requirement like the previous examples in the U.K. and the U.S., the Canadian Institutes of Health Research (CIHR) and the National Science and Engineering Research Council (NSERC) provide funding to research projects which may involve community engagement.[21] However, for such agencies that do not already have a SciComm criterion, there is a growing call to include this as a requirement for funding opportunities.[21]

As such, SciComm skills are now considered not only an asset but also a requirement for scientists. Sir Mark Walport, the U.K. government's Chief Scientific Advisor of 2013 to 2017, emphasized this in an interview: "Science isn't finished until it's communicated. The communication to wider audiences is part of the job of being a scientist, and so how you communicate is absolutely vital".[23]

1.4 What is SciComm Training and Why is it Important?

Knowing the implications of SciComm and the importance of effective SciComm practices, how can we ensure that scientists have the skillset to successfully disseminate their knowledge to various audiences? As mentioned earlier, this is where SciComm training programs step in, aiming to provide scientists with an opportunity to acquire and practice such skills.[9] Considering the crucial role that these trainings can bear in shaping a scientist's practices, it is reasonable to state that the earlier training takes place, the more beneficial it is.[24] This would maximize scientists' exposure to SciComm and their likelihood of fulfilling their role as *civic scientists*. Indeed, research into existing SciComm training programs on the undergraduate and graduate levels has revealed the many benefits of these programs, two of which include enhancing scientists' confidence and sense of belonging.

Confidence refers to scientists' belief in their ability to effectively communicate science with different audiences. In a U. K. study, researchers explored the impacts of an undergraduate SciComm module on science students, and concluded that those who completed the module were more confident during PhD interviews.[25] Similarly, Brownell & colleagues (2013) looked into the impacts of a Stanford University upper-level undergraduate Biology course with SciComm-focused assessments for 3 consecutive years. Based on survey results, students had a confidence boost in both communicating science with other scientists and with lay audiences after taking the course.[26] Participant surveys from other training programs in North America, specifically the ones offered by UNAVCO, the EarthScopeNationalOffice and the Incorporated Research Institutions for Seismology (IRIS), have also shown positive impacts on scientists' confidence in communicating with lay audiences.[27] In addition, highlighting the important role of confidence for science communicators, the IPCC released a SciComm handbook for their authors back in 2018. While acknowledging that *how* a messenger communicates a message is at least just as important as the message itself, this was released in hopes of enhancing the scientists' confidence in public engagement.[10] A summary of the guidelines is shown in Fig. 1.

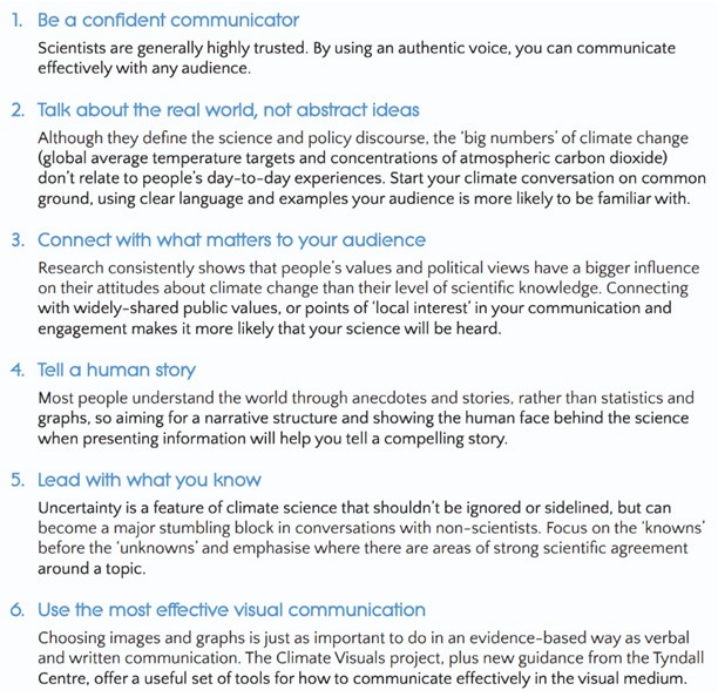

Figure 1. **IPCC's principles for authors to use in public engagement, as seen in their 2018 communications handbook**

Research into the aforementioned North American SciComm training programs has also revealed an enhanced sense of belonging at scientific meetings for the participants.[27] The researchers noted that this plays a critical role when it comes to student retention within the science field.[27] A sense of belonging to the institution and the academic community has been associated with greater student retention in previous studies as well. [28,29] For undergraduate students, this involves not only persistence in one's current program, but also pursuing research in the field through a Master's or a PhD degree.

1.5 ComSciConCAN and the Present Study

The Communicating Science Conference (ComSciCon) is an annual SciComm workshop series founded in the U.S. in 2013. This conference, run by graduate students, aims to empower North American STEM graduate students to share their research with not only other experts in the field, but further, with a broad range of audiences. To accomplish this goal, participants are provided with an opportunity to develop and finetune their SciComm skills through a variety of activities. These include learning about effective SciComm through panel discussions with invited SciComm experts (science writers, filmmakers, etc.), networking with the guests and other participants, and putting their newly gained knowledge to practice for written and oral SciComm through hands-on training sessions.[30] A study into the impacts of U.S. regional ComSciCon workshops in 2015-2017 found significant improvements in attendees' confidence levels for communicating science with different audiences.[31]

ComSciConCAN is an adaptation of the ComSciCon workshops within Canada and, as such, is designed to help STEM graduate students improve their skills in communicating their research with a variety of audiences. In 2021, this conference took place virtually on August 13th-15th, and comprised of the following components:

a) Panel discussions with both SciComm experts from diverse academic backgrounds and those involved in science policy,

b) Workshops on data visualization and visual storytelling,

c) "Create-a-thon", through which attendees developed a SciComm piece (in the format of their choosing), and received constructive feedback from a peer review group prior to the conference, and from a SciComm expert throughout the conference, and

d) An E-poster session, which aimed to highlight the attendees' SciComm contributions through abstract submissions and was an optional component.

Although the study by O'Keeffe and Bain (2018), as well as many other studies, have explored the outcomes of various SciComm training programs in different parts of the world, there is a gap in knowledge regarding the impacts of the ComSciConCAN workshop series. This paper will analyze this topic with a specific focus on attendees' confidence in publishing in popular science magazines and communicating science with different audiences, as well as their sense of belonging to the scientific community. Based on previous research findings regarding similar SciComm training programs, it is hypothesized that participation in this conference will indeed have a positive impact on both the confidence and sense of belonging of the participants.

METHODS

2.1 Data Collection: Surveys

To assess the effectiveness of ComSciConCAN-2021, all attendees were asked to complete online pre- and post- workshop surveys at least a few weeks apart in all instances. Similar surveys have been used previously for the purpose of assessing the effectiveness of the ComSciCon workshops in the U.S.[31] The pre-workshop survey contained 41 questions, and included ones that asked the attendees to rate their confidence level with regards to each of the following on a scale of 1 (not at all confident) to 9 (very confident): comfortability with submitting an article to a popular science medium (e.g. Scientific American, Wired, etc.), their ability to communicate science with other scientists, and their ability to communicate science with the general public. The survey after the conference asked the participants the same questions about confidence levels. Additionally, the post-workshop survey aimed to explore the impact of the conference on sense of belonging by asking the participants to indicate their level of agreement (strongly agree, somewhat agree, neutral, somewhat disagree, and strongly disagree) with statements indicating that these workshops will positively impact their sense of belonging to both their current STEM program and SciComm activities.

As the Canadian participant pool consisted of both English and French-speaking individuals, all workshops and surveys were run in both languages. Survey results were then translated to English for data analysis.

2.2 Data Analysis and Statistical Tests

Upon data collection, pre- and post- workshop survey responses were organized in an Excel spreadsheet. The use of identical questions regarding confidence in both surveys allowed for effective statistical analysis. The software Graphpad was used to conduct unpaired t-

test analysis, which allowed for the comparison of mean levels of confidence reported pre- and post- conference and to determine whether any meaningful difference existed between the two measures. Bar graphs and box and whisker plots were used to present the results. While no statistical analysis could be done for the data gathered regarding the sense of belonging, the frequency of each level of agreement was counted and pie charts were used to present these data. All results, including the figures mentioned, are shown in the following results section.

RESULTS

Here, we present findings from the online surveys regarding both confidence levels and sense of belonging, as reported by ComSciConCAN-2021 participants.

3.1 ComSciConCAN and its Impacts on Confidence

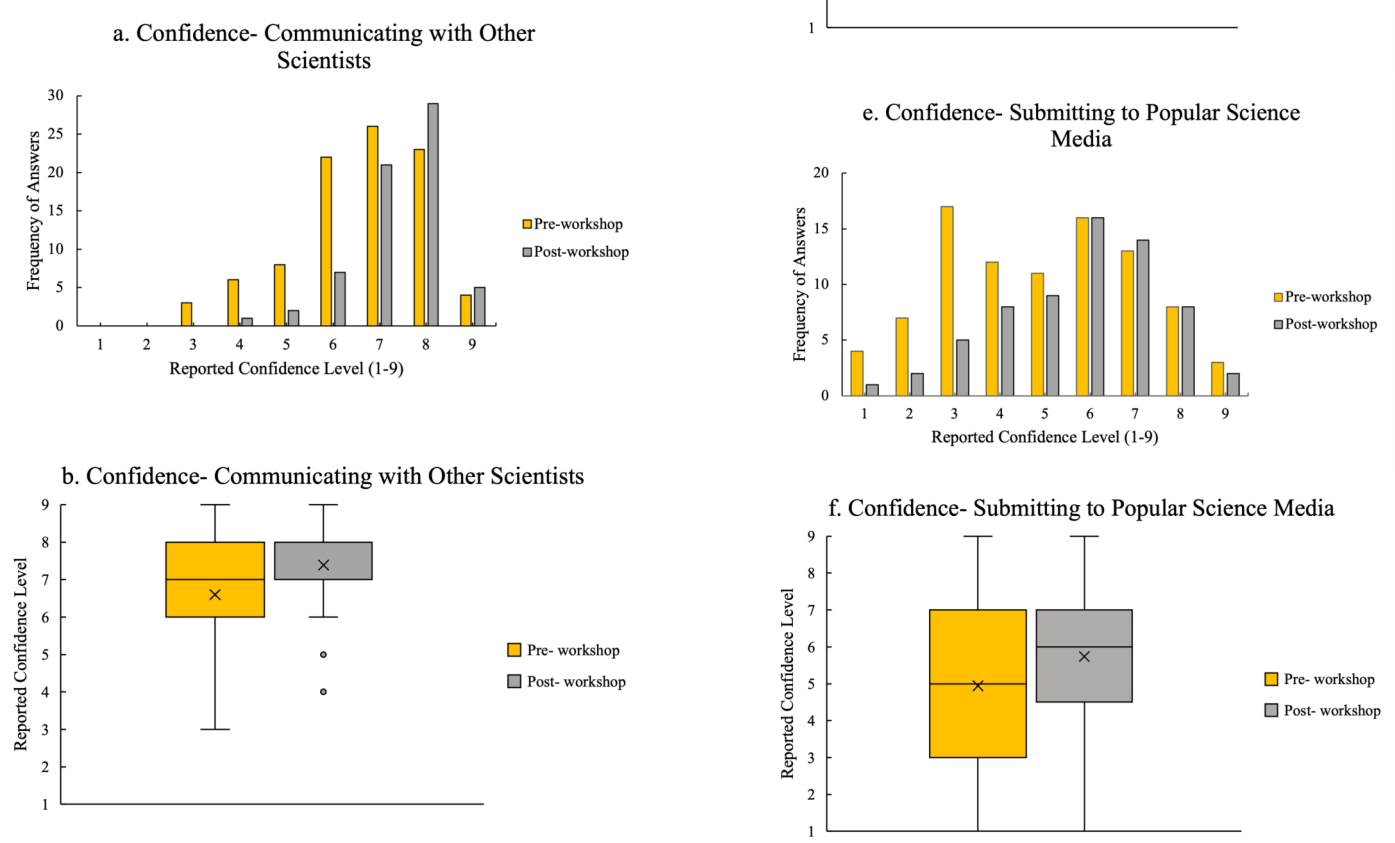

Figure 2. The change in attendees' self-reported confidence levels (from 1 to 9, where 1 = "not at all confident" and 9 = "very confident") regarding communication with various audiences pre- and post- workshop. Panels a and b display the results for communicating with other scientists, panels c and d display results for communicating with the general public, and panels e and f are for submission to popular science media. The bar graphs in panels a, c, and e depict the general trends observed in the attendees' confidence levels, while panels b, d, and f depict this information using box and whisker plots, highlighting the difference in means (presented by an "x" in each box). The p- values associated with the differences in means seen in panels b, d, and f are all smaller than 0.05. These values are 0.0002, 0.0001, and 0.0142 respectively.

As seen in all bar graphs in Fig. 2, there was a general shift to the right after the conference, indicating higher self- reported confidence levels by attendees post- versus pre- workshops. This difference can also be seen in all box and whisker plots in Fig. 2. These graphs show this shift through a reduction in size of each box (where 50% of data points lie) post- workshops, the shift in mean confidence values reported as well as a shortened whisker length in panels b and d. Any data point with a confidence level smaller than 6 is shown to be an outlier in these two panels, b and d. The box and whisker plots also compare the mean levels of confidence before and after workshops, and present an increase in this value in each case (from 6.598 to 7.385, 6.462 to 7.277, and 4.945 to 5.738, pre- versus post- workshops for communication with scientists, communication with the general public, and submission to popular scientific journals, respectively). Statistical analysis showed these differences to be significant, and the p-values are included in the figure caption for Fig. 2.

3.2 ComSciConCAN and its Impacts on Sense of Belonging

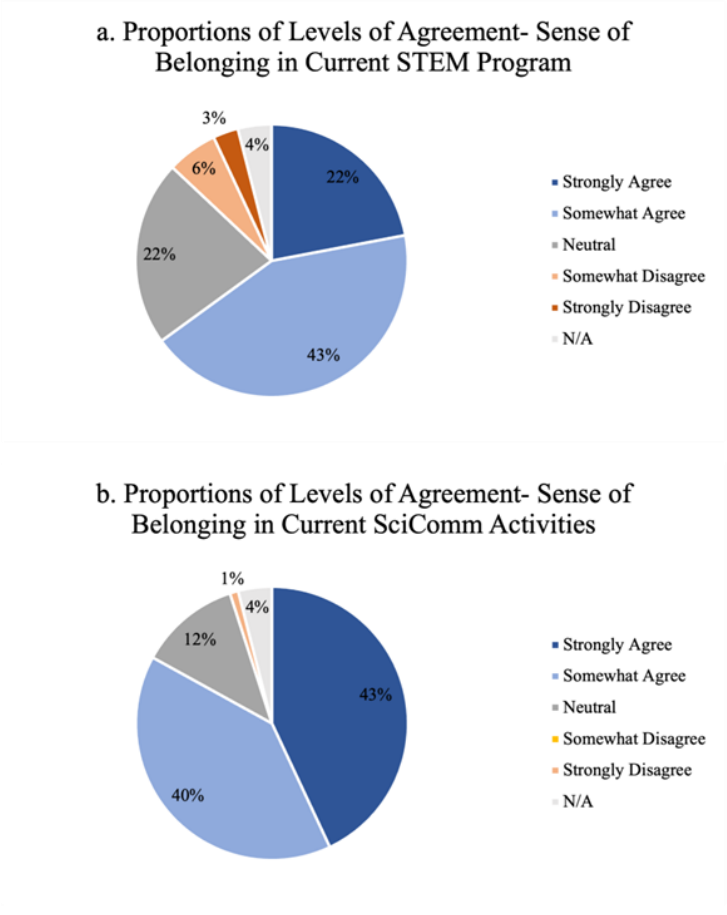

Figure 3. Levels of agreement with each statement regarding sense of belonging. The pie chart in panel a presents the results for the statement "ComSciCon Canada will increase my sense of belonging in my current STEM program," and that in panel b presents this information for the statement "ComSciCon Canada will increase my sense of belonging in my current sci comm activities."

As seen in Fig. 3 panel a, 65% of participants at least "somewhat agreed" that the workshops will be helpful in improving their sense of belonging in their current STEM program, with 22% of them strongly agreeing. Similarly, and as seen in Fig. 3 panel b, 83% of participants at least "somewhat agreed" that attending ComSciConCAN will have a positive role in improving their sense of belonging in their current SciComm activities, with 43% of them strongly agreeing.

DISCUSSION

4.1 ComSciConCAN and its Impacts on Sense of Belonging

The purpose of this study was to determine whether participating in the ComSciConCAN workshops had a positive impact on both the confidence and sense of belonging of graduate STEM students. Our hypothesis was that this impact would in fact be observed, which was tested through online pre- and post- workshop surveys.

As shown in Fig. 2, there was an increase in attendees' self- reported confidence levels after the workshops. Further analysis showed this difference between pre- and post- workshop confidence levels to be statistically significant (with p-values smaller than 0.05 in each case). This supports the first part of our hypothesis, which predicted a positive impact on confidence in communicating science with different audiences. As the surveys were sent at least a few weeks apart in every instance, it is unlikely that the participants remembered their original confidence levels reported. This eliminates a source of error that could potentially impact the results by reducing subjectivity in answering the post- workshop survey questions. These findings regarding a boost in confidence are consistent with the findings of previous studies on other SciComm training programs.[25-27,31] Particularly, O'Keeffe & Bain (2018) investigated the impacts of U.S. regional ComSciCon workshops on identical measures- confidence in communicating with other scientists and the general public, and in submitting to popular scientific outlets- and found similar statistically meaningful results.

Similarly, the attendees' perception of whether the workshops will improve their sense of belonging provides support for the latter part of our hypothesis. This is since a great proportion of the attendees (65% for sense of belonging in current STEM program and 83% for sense of belonging in current SciComm activities) at least somewhat agreed with the respective state-

ments. These findings are similar to those from previous post-training surveys for other SciComm training programs, which have found an enhanced sense of belonging at scientific meetings and to STEM fields as a result of attending these workshops.[27]

4.2 Limitations

There are some limitations to this study due to self-reporting. These include barriers associated with honesty (the participants may have been inclined to report more socially desirable answers), introspective ability (participants may have not been able to objectively assess themselves), interpretation of questions (different individuals may have interpreted the wording of the survey questions differently), and rating scales (the participants may have been inclined to give an extreme or middle answer to all questions). In addition, although 94 individuals completed the pre- workshop surveys, only 68 entries were received for the post- workshop surveys. This translates into an approximately 28% attrition rate, leaving open the possibility that the results/ positive impacts of the conference may have been an inflation of true results.

4.3 Next Steps

In the future, research studies can explore the outlined benefits of SciComm training programs, specifically ComSciCon in North America, to see whether the results of our study can be replicated. Our findings highlight some of the notable impacts of the ComSciCon workshop series, and provide support for other SciComm training program coordinators to adopt the framework used by ComSciCon to design new SciComm training programs. This also highlights the importance of funding opportunities to support these programs and provide the ground for SciComm experts to expand training and run these programs for a larger body of STEM students.

CONCLUSION

This study was designed to investigate the impacts of the ComSciConCAN workshops on STEM graduate students' confidence in communicating with both expert and lay audiences and their sense of belonging to the scientific community. We predicted, based on the findings of previous studies on various SciComm training programs, that a positive impact would result. In line with this hypothesis and through analyzing the participants' observations pre- versus post- workshops, we discovered meaningful improvement in the scientists' SciComm confidence in all three categories: communicating with other scientists, communicating with the general public, and submitting to popular science media. Also, upon attending the conference, a greater proportion of the participants more strongly believed that the workshops will enhance their sense of belonging in STEM activities.

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