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A comparison between scientists' and communication scholars' views about scientists' public engagement activities

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Abstract

This study investigated how communication scholars view scientists' public engagement as well as differences between how these scholars and natural and physical scientists think about the topic. The study used surveys of authors who recently published in five journals related to science communication alongside surveys of scientists from three prominent professional science societies. The results suggest that communication scholars ($N = 362$) shared some views with the scientists ($N = 307$, 373, 372) regarding scientists' performance, factors that influence engagement activities, and communication objectives, but potentially important differences were observed as well. Scientists have more positive beliefs about engagement norms and also rate their engagement efficacy relatively high. But communication scholars have higher expectations for online engagement amount. The findings address gaps in perceptions and performances from these two communities and suggest areas of potential emphasis for science communication training.

Keywords

communication scholars, communication training, science communication

1. Introduction

The current study aims to compare how science communication scholars and natural scientists think about science communication as public engagement. Science communication and public

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engagement are understood here as opportunities for scientific communities and various publics to interact and have meaningful dialogues (Selvakumar and Storksdieck, 2013). Underlying this research focus is a question of the degree to which science communication scholarship regarding what constitutes effective communication is reflected in scientists' public engagement views and behavior and provides useful insights for scientists in the forms of training or other kinds of guidance.

Leaders in the science community are increasingly calling on scientists to communicate more frequently and more effectively with their fellow citizens across a range of formats and channels (Cicerone, 2006; Department of Science and Technology: South Africa, 2014; European Union, 2002; Holt, 2015; Jia and Liu, 2014; Leshner, 2007; National Academies of Sciences, Engineering, and Medicine, 2016; National Research Council, 1989; The Royal Society, 1985). This engagement by scientists could include direct modes of face-to-face interaction, such as those that might occur in museums, science festivals, science cafés, and other community-based events; conversations with policy makers; engaging activities conducted through online channels; as well as indirect or mediated engagement through interactions with journalists or television.

Given that communication between scientists and the public is already occurring (Besley et al., 2017; Rainie et al., 2015), and more is expected, it seems likely that communication training could play a useful role in helping scientists engage with the public more effectively. Effectiveness, in this regard, would involve helping scientists set and meet their science communication goals (Hon, 1998) while also recognizing that non-scientists who communicate science have their own goals and expectations. Available communication training varies and includes activities such as courses at universities, fellowships that include training, and stand-alone seminars and workshops designed to prepare scientists for more effective interactions with the public and media. Training content typically includes the acquisition of communication skills such as presentation skills, message refinement skills, and technical skills related to using the communication technologies like video, audio, and online publishing (Besley et al., 2016). However, based on several researchers' findings, it also appears there is still a substantial disconnect between the training and practice of communication scholarship (Besley et al., 2016; Besley and Tanner, 2011; Miller et al., 2009). One longstanding concern of science communicators is the prevalence of "deficit model" thinking—the belief that public skepticism and hostility to science and technology is due to a lack of information and understanding, which is commonly observed in scientists' engagement practice.

The current study is based on the idea that communication scholars have developed a deeper understanding of what can make communication effective but that they are not the ones doing most science communication. Rather, scientists hold a central position when it comes to communicating about science due both to their role as the creators of new knowledge and to the high level of trust that the public has in scientists (Fiske et al., 2007; Funk, 2017; National Science Board, 2016). The purpose of the current study is therefore to directly compare the views of scientists and communication scholars to better understand where these two groups may share similar perspectives and where they may have different points of view. By doing so we aim to help point to areas that those involved in science communication training and science communication support might revise or emphasize. In other words, any substantive disconnect between what science communication scholars and scientists think about effective engagement represents a potential opportunity to shift training emphases, helping scientists think about communication in ways that communication scholarship suggests may be effective. It is also important for communication scholars to remain open to the insights of practitioners.

We intentionally define the population of science communication scholars broadly to include any researcher who has published in a core science, health, or risk communication focused journal to capture the viewpoints of experts from related subfields. We use a relatively broad understanding of

public engagement activities to include any efforts by members of the scientific community to engage non-scientists, primarily through communication. We fully recognize that much of the communication that occurs is likely to be one-way communication that falls short of normative standards of public engagement as meaningful, multi-party dialogue as described by scholars focused on public deliberation (Delli Carpini et al., 2004). Nevertheless, the surveys underlying the current research asked about engagement activities, and thus that term is foregrounded here.

It is also noteworthy that the current study seeks to provide a largely descriptive understanding of potential differences between scientists and science communication efforts as part of a broader effort to improve communication practice. It does not, in this regard, seek to test theories about why scientists might differ from communication scholars. There is little past research that speaks to this type of comparison. Research questions are therefore used to organize both the literature and the results described below with the discussion section highlighting areas for future theory building. In the following section, we focus on the factors related to scientists' engagement activities, including the amount of engagement by modalities, predictors of engagement behavior, and objectives of engagement activities. In addition, we also explore science communication scholars' involvement in public engagement, such as science communication training.

2. Literature review

Engagement types and quantity

Non-scientists receive news and information about science and technology through a wide variety of channels. These include newspapers, television, and online news sources (Mitchell et al., 2016; National Science Board, 2016), as well as directly from scientists on occasions such as museum visits and science festivals (Jensen and Buckley, 2012).

Scientists view themselves as having an important role to play in societal decision-making (Besley and Nisbet, 2013). A survey with UK scientists in 2015 (Hamlyn et al., 2015) indicates that most scientists there are communicating with the public about science in some way. This survey revealed that about 78% of scientists reported that they participated in public engagement activities at least once a year, which was a small rise compared with the data from 2006 (The Royal Society, 2006). In the United States, a 2015 Pew Research Center study (Rainie et al., 2015) with over 3700 scientists similarly found that only about 2% say they "never" talk to non-scientists about their work, while 45% say they never talk to journalists. About 24% say they blog about science and their research, and 47% say they use social media to talk about science.

What is not addressed in these types of statistics is what would represent an appropriate level of engagement via different modalities. The first part of this study aims to compare the amount of engagement that scientists actually report with the amount of engagement that our sample of communication scholars expects. More importantly, this research question aims to compare scientists' and communication scholars' perception of communication via specific modalities. Asking this question does not suggest that communication scholars should have unique or correct knowledge about what would constitute appropriate levels of engagement. However, it seems useful to know if communication scholars are expecting more or less engagement than scientists are providing, and whether scientists prioritize communication modalities differently to what scholars expect. An unrecognized difference in perspectives might, in this regard, create difficulties in training discussions relative to engagement amount:

RQ1. How frequent do scientists conduct science communication activities, compared with communication scholars' expectation?

Predictors of engagement

While the amount of communication training and activity is important, a further goal of the current study is to assess the degree to which communication scholars and scientists may have different perceptions of factors known to predict engagement behavior. However, no studies, to our knowledge, have sought to see if communication scholars and scientists might have different beliefs about these predictors. In the current study, we therefore argue that it is also important to understand any differences between how communication experts and scientists view the factors that may influence scientists' engagement behavior.

A number of studies have investigated the factors that are associated with scientists' engagement, including demographic information such as age and experience (e.g. Jensen, 2010; Rainie et al., 2015) or gender (i.e. Bentley and Kyvik, 2010; Crettaz von Roten, 2010). Meanwhile, a small number of studies have attempted to use theory to explore the factors that predict scientists' engagement behavior (e.g. Dunwoody et al., 2009; Poliakoff and Webb, 2007).

Much of this literature has been guided by the *theory of planned behavior* (TPB). This body of research is one of the most used models in science, environment, and health communication literature to predict behavior (e.g. Poliakoff and Webb, 2007; Trumbo, 2001). The TPB posits that three factors drive behavioral intention: attitudes toward the behavior, perceived norms related to the behavior, and perceived behavioral control (i.e. efficacy) (Ajzen, 1991). The logic of drawing on the TPB is that scientists' engagement activities can be considered as intended behaviors. It is expected that those who organize communication training have a range of opportunities to try to address scientists' engagement-related attitudes, and beliefs about norms and efficacy. Next, we review and investigate the potential disconnect between scientists and communication scholars in some of the factors that influence scientists' engagement activities.

When it comes to attitudes, not surprisingly, science communication scholars have found consistent results in scientists' positive attitudes toward public engagement, and a positive association between positive attitudes toward engagement and engagement activities (Besley et al., 2013; Martin-Sempere et al., 2008). The recent Pew Report that surveyed scientist members of the American Association for the Advancement of Science (AAAS) showed 87% of them agree that "scientists should take an active role in public policy debates about issues related to science and technology" (Rainie et al., 2015). Many studies have revealed consistent findings that scientists who have more positive attitudes toward public engagement, including general attitudes to engagement (Poliakoff and Webb, 2007), perceived benefit from engagement (Dudo et al., 2014), perceived enjoyment (Besley et al., 2018), or perceived moral duty (Tsfati et al., 2011), are more likely to conduct more engagement activities.

The current study considers two types of normative beliefs, including what scientists think their colleagues are doing (i.e. descriptive norms) and what they think a specific referent group such as their colleagues would support (i.e. injunctive or subjective norms). Subjective norm is also an important factor in TPB (Ajzen, 1991). While the referent group could encompass those outside academic communities, like scientists' friends and families, the current study focuses mostly on the normative influence of scientist community members and scientists' colleagues in general. Previous research has found a paucity of evidence that norms are associated with scientists' willingness to engage, yet norm-related factors—such as perceived pressure from peer colleagues to perform or not perform certain behaviors—appear to be a predictor of scientists' engagement behavior in certain area, such as with biomedical researchers (Dudo, 2012). Although there is a lack of evidence on the relationship between social norms and engagement, it remains important to understand normative beliefs because many writers appear to believe that scientists are not engaging because of fear of social sanction—the so-called Sagan Effect (Ecklund et al., 2012; Russo, 2010).

Meanwhile, we are also interested in how communication scholars view social norms as this may affect the degree to which norms are addressed as part of training. Therefore, a research question on social norm is asked:

RQ2. To what extent do scientists and communication scholars perceive social norms about public engagement differently?

Another important predictor within the TPB, perceived behavioral control, can also be understood as efficacy (Bandura, 1977), or the individual's belief of their capability and resource to perform certain behaviors successfully. Several studies have shown that scientists are not very confident with their skills and ability to perform science communication (The Royal Society, 2006; Weigold, 2001), and scientists who believe that they can perform well in science communication are more likely to engage (Dudo et al., 2014; Dunwoody et al., 2009). This lack of communication skills realized by scientists (Poliakoff and Webb, 2007) also illustrates the need for more effective science communication training. Moreover, the switch from traditional one-way communication between scientists and the public to interactive two-way engagement has many scientists and institutions starting to rethink the skills scientists need in order to accomplish this transmission (Yuan et al., 2017). In the current study, we asked several types of efficacy, including scientists' engaging skills, belief that engaging can have a beneficial effect, and belief that they have the time to engage. Therefore, we also ask the following research question on efficacy:

RQ3. To what extent do scientists and communication scholars perceive scientists' public engagement efficacy differently?

In addition, we look at another potential factor that may affect scientists' engagement activities—attitudes toward the public. In other words, how do scientists view their public audiences? As a study that focuses on the quality of science communication, the value of understanding this question is to also better capture scientists' attitudes toward engagement behavior. Literature on deference toward scientific authority describes the idea that public attitudes toward science and technology are built on the influences of different types of trust, including the trust and deference toward scientific authority (Brossard and Nisbet, 2006; Lee and Scheufele, 2006). In other words, how does the public view scientific communities or scientists? On the other hand, previous studies suggest that scientists saw the public and the media as deficient in scientific knowledge and ability (Besley and Nisbet, 2013), and scientists who had negative views about their expected public audiences might be less willing to participate in online engagement (Besley, 2014). Given the contribution scientists' attitudes make toward how they view engagement and the public, knowing scientists' perception of the public, and if any differences exist between scientists and scholars, would highlight the need for discussions that could be addressed through training.

RQ4. To what extent do scientists and communication scholars differ in terms of their perception of public regarding public engagement?

Engagement objectives

Besides the factors motivating scientists to participate in public engagement activities, it is also critical for scientists to make choices about what they want to say and do during engagement, as a way to improve the quality of engagement efforts. Ideally, they would choose their words and

actions based on a desire to achieve specific communication objectives (Besley et al., 2017). It should further be hoped that they would choose objectives that have the potential to affect scientists' actual goals for engagement (e.g. science-based policy or individual behavior). Past research shows that, although scientists may report positive attitudes toward public engagement, these reports tend to exclude any discussion of the objectives scientists plan to achieve with the engagement (Besley et al., 2016). Meanwhile, the community of science communication scholars widely agrees that science communication in which the sole objective is communicating facts—or correcting a "knowledge deficit"—has never been a realistic path to behavior change or policy support (Sturgis and Allum, 2004). Instead, science communication scholars recommend more meaningful, interactive models of dialogue between the scientific community and the public where the objectives may include sharing knowledge alongside other objectives such as building trust, a sense of shared identity (Besley et al., 2015), or reframing an issue (Nisbet, 2010). Many studies also, however, discuss the challenge of facilitating meaningful dialogue between scientists and interested publics (i.e. Trench and Miller, 2012). Borrowing from strategic communication research (Hon, 1998), a few science communication scholars have categorized different types of objectives scientists may have (Besley et al., 2017; Dudo and Besley, 2016), and have explored science communication trainers' view of them (Besley et al., 2016), including traditional objectives such as "informing people about scientific issues" and "defending science from those who spread falsehoods," as well as other objectives like "getting people interested or excited about science," "demonstrating the scientific community's openness and transparency," and so on. The expectation is that communication that helps scientists achieve such objectives can help contribute to achieving the long-term goals of scientists. If there is a difference in objective prioritization between scientists and communication scholars, there might be an argument for designing training to help scientists rethink their communication priorities. The specific objectives addressed in the current study are not meant to be exhaustive but are based on the authors' understanding of the underlying literature and previous research (Besley, Dudo, Yuan, & AbiGhannam, 2016):

RQ5. In comparison to scientists, how do communication scholars prioritize a set of different communication objectives?

Communication scholars' involvement

Science communication scholars also play an important role in public engagement. Although science communication scholars may not be the ones doing most science communication, their research and other indirect involvement may provide a deep understanding of what can make communication effective. Moreover, while the quantity of engagement is important, the current study also seeks to understand how scientists and communication scholars think about issues associated with engagement quality. One way to improve quality is to increase training quality. We broadly define science communication training as any activity wherein individuals from scientific communities receive structured advice and guidance on how to effectively communicate about science and engage with the public. Science communication training includes activities on communication skills and also emphasizes the value of creating dialogue between scientists and the broader societies (Nisbet and Scheufele, 2009). One past study identified more than 40 active North American–based training programs (Besley et al., 2016), and the number of training programs for undergraduate and graduate students has been increasing (Basken, 2009). The types of science communication trainers include professional full-time and part-time trainers, as well as communication scholars in places such as universities and practitioners in museums, zoos, and aquariums. Training is also

sometimes done by scholars with communication experience but who do not study communication (Besley et al., 2015). Past research has also found that, in general, scientists have positive attitudes toward training (Besley et al., 2015) and scientists who participated in trainings are more likely to engage with the public (The Royal Society, 2006).

The importance of science communication training has been recognized not only by scientists but also by communication scholars, especially those who research topics related to science communication. Besley and Tanner (2011) looked at science communication scholars' perceptions of scientists' needs from trainings and showed that communication scholars largely agree that scientists could benefit from additional communication trainings. The rationale for involving communication scholars in this type of research is that their expertise in science communication–related disciplines might provide insights that can increase the effectiveness of public communication. Furthermore, communication scholars could also provide suggestions on how to better organize and facilitate science communication trainings and serve as trainers. An example is the communication training workshop series organized by the European Science Communication Network, which provided scientists training on message delivery, and taught them skills for communicating with media and how to communicate dialogically (Miller et al., 2009). Nisbet and Scheufele (2009) also argued that social science on the public's understanding and participation in societal decision-making can be useful for guiding science communication engagement and facilitate understandings of the role of media and the public in such a process. A recent report from National Academies of Sciences also illustrates the importance of training efforts that help to form partnership between scientists and practitioners to translate scientific findings into messages for the public (National Academies of Sciences, Engineering, and Medicine, 2017).

Given our interest in the possible role of communication scholars in training, it also seems important to explore the extent to which science communication scholars are involved in training scientists about certain communication skills, such as the types of science communicators they train (scientists or engineers, science/health regulators, journalists/communication professionals, etc.) and the focus of their trainings (media interviews, public speaking, etc.):

RQ6. How involved are science communication scholars in various types of science communication training?

To sum up, this study builds on the factors that influence scientists' engagement performances from past research, as well as the different ideas science communication scholars and scientists may have, about the amount of engagement (RQ1), normative beliefs (RQ2), perceived efficacy (RQ3), attitudes toward the public (RQ4), and how they prioritize communication objectives (RQ5). Lastly, we seek to clarify the extent of science communication scholars' involvement in science communication training (RQ6).

3. Method

Sampling

The online survey with communication scholars was conducted in April 2016. We broadly defined science communication experts as scholars in the fields of science, health, environment, and risk communication in general. Thus, the authors compiled a list of first and second authors who had publications in science, health, and risk communication–related journals between January 2011 and December 2015. These journals included *Journal of Health Communication; Health Communication; Science Communication; Public Understanding of Science; International Journal of Science*

Education, Part B; and *Risk Analysis*. For *Risk Analysis*, only articles with the keyword "communication" were included because this journal also publishes non-communication research. This sampling strategy has been used in previous studies (Besley and Tanner, 2011; Farley et al., 2013; Peters et al., 2008) and seemed to be an appropriate approach to identify researchers who have studied science-focused public engagement–related topics. Contact information for 2331 scholars was collected, but removal of duplicates resulted in a final sample of 1677. Of these, 363 scholars responded and finished the survey, with a response rate of 22%. There is no margin of sampling error as the survey was an attempted census of the underlying population of authors. Of course, as with any survey, there is always the potential for measurement error and non-response bias. An initial email and three reminders were sent, each with slightly different messages (Dillman et al., 2009).

For the sample of scientists, three natural science societies—a general scientific society, a biological society, and a geophysical society—were included in the current study to allow for a deeper comparison between natural scientists and communication scholars. The three online surveys with society members took place via several waves of data collection at different times between October 2015 and March 2016. For each society, an invitation email was sent from the society members with a link to the online survey. Depending on what the society allowed, this initial email was followed by either three or four reminders. The survey started with a set of questions about past engagement behavior and future willingness to engage. Participants from the general scientific society and the geophysical society were then randomly assigned to questions focused on one of three modes of public engagement: face-to-face, mediated, or online communication. In contrast, participants from the biological society were assigned to evaluate face-to-face communication only because of the small number of members in the society. A total of 1064 respondents from the general scientific society (response rate: 7%), 376 respondents from the biological society (response rate: 6%), and 1013 respondents from geophysical society (response rate: 10%) finished the survey and had usable data. The society names are not disclosed per the agreement with societies and to assure them that the project's goal was not to rank or rate societies or fields.

The current study focuses only on respondents in the face-to-face communication condition because the small population of communication scholars, coupled with a desire to keep survey length down, made it impractical to ask about multiple engagement modes. It seemed important to ask about engagement in the context of a single mode (i.e. face-to-face) because of a concern that views might vary across modes. Indeed, it should be expected that views on engagement would vary substantially for different forms of face-to-face engagement, but it was expected that scholars would be able to accept some level of generality. Moreover, because the knowledge level and occupations of members in different societies vary, the current study only selected respondents holding a PhD degree at American universities. This limit in scope primarily affected the scientific societies, two of which had large numbers of members working in private and governmental sectors. Ultimately, the smallest available sample came from the geophysical society ($n = 307$), while the largest sample came from the general society ($n = 373$).

Survey structure

The surveys for scientists and communication scholars were similarly structured and mainly focused on the face-to-face aspect of public engagement. The survey for scientists was phrased to solicit an evaluation of their own behavior and perception of public engagement, while the survey questions answered by the communication scholars typically asked participants to evaluate what they knew about scientists' behaviors and perceptions of public engagement.

The survey itself typically took between 15 and 30 minutes to finish. As noted, the survey started with questions about past and future public engagement behaviors. Questions then focused

on goals for public engagement, overall attitudes, and beliefs about norms and efficacy associated with face-to-face engagement. There were then questions about communication objectives in the context of face-to-face engagement activities. The questions in the goals and objectives blocks were presented in random order. Exact question wording is presented along with the descriptive statistics in the tables.

Analysis

A series of descriptive analyses and mean comparisons using analysis of variance (ANOVA) with post hoc analyses were conducted to compare between communication scholars and scientists from the three different societies included in the study. These included ANOVAs for past science communication behavior (RQ1), social norms (RQ2), scientists' efficacy (RQ3), scientists' views of the public (RQ4), and perception of different communication objectives (RQ5). Frequency tests were also conducted to present communication scholars' training involvement (RQ6).

4. Results

Scientists' behavior and communication scholars' expectations

If we rely on the robustness of ANOVA and treat the scientists' responses to the ordinal response scale as continuous measures, it might be said that scientists from the three science societies reported participation in engagement activities as, on average, "between 2 to 5 times in the last year," with the numbers varying slightly between the biological society and the other two societies (RQ1; Table 1). However, communication scholars indicated that they expected scientists to engage more than scientists actually did. Communication scholars' expectation varies from 2–5 times (M_{comm} = 2.93, standard error (SE) = .06, policy-maker engagement) to 6 times (M_{comm} = 3.93, SE = .09, online engagement) per year, while scientists' actual engagement varies from between never and once ($M_{scientist}$ = 1.48, SE = .04, policy-maker engagement from biological society) to nearly 2–5 times ($M_{scientist}$ = 2.71, SE = .09–.12, both online and face-to-face engagement from geophysical society). There are also slight differences between scientific societies. For instance, scientists from the geophysical society reported slightly more of all engagement types, followed by the general society and the biological society. More generally, online and face-to-face engagements were generally seen by communication scholars as most needed, where they were most often conducted by scientists as well. Policy-maker engagement was viewed as the type of engagement where the least regular engagement was needed or conducted. We also ranked the amount of engagement for each group by communication modalities. The results showed that online engagement is the top one priority compared with other types of communication while scientists privileged face-to-face communication more than others. Communication scholars indicated that they thought online engagement (M_{comm} = 3.93, SE = .93) needed to be the more regular than face-to-face engagement (M_{comm} = 3.29, SE = .06), while the scientist samples were most likely to indicate that they spent the most time on face-to-face engagement ($M_{General}$ = 2.68, $SE_{General}$ = .08; $M_{Geophysical}$ = 2.71, $SE_{Geophysical}$ = .09; $M_{Biological}$ = 2.20, $SE_{Biological}$ = .07) compared with the online engagement ($M_{General}$ = 2.32, $SE_{General}$ = .10; $M_{Geophysical}$ = 2.71, $SE_{Geophysical}$ = .12; $M_{Biological}$ = 2.04, $SE_{Biological}$ = .09) (Table 1).

Factors that affect engagement activities

We also surveyed scientists and communication scholars about their perceptions of social norms (RQ2; Table 2). In general, scientists appear to be more likely to believe that their colleagues are

Table 1. Scientists' self-reported past behavior and expectation from communication scholars.

	Communication scholars (should engage …)			General society			Geophysical society			Biological society			*F* (significance)
	M	*SE*	*R*	*M*	*SE*	*R*	*M*	*SE*	*R*	*M*	*SE*	*R*	
Online engagement	3.93[a]	.09	1	2.32[c]	.10	2	2.71[b]	.12	1	2.04[c]	.09	2	81.35**
Face-to-face engagement	3.29[a]	.06	2	2.68[b]	.08	1	2.71[b]	.09	1	2.20[c]	.07	1	38.45**
Mediated engagement	3.16[a]	.06	3	2.10[b]	.07	3	2.31[b]	.08	3	1.60[c]	.05	3	120.58**
Policy-maker engagement	2.93[a]	.06	4	1.83[b]	.06	4	1.82[b]	.07	4	1.48[c]	.04	4	130.83**

SE: standard error; *R*: ranking; HSD: honestly significant difference.
Superscript letters "a, b, c" indicate the group comparison from post hoc test (Tukey's HSD).
1 = never, 2 = once, 3 = 2 to 5 times, 4 = 6 to 11 times, 5 = about once a month.
**$p < .01$.

engaging ($M_{scientist}$ = 3.65–5.36, SE = .06–.08) than communication scholars (M_{comm} = 2.71–4.70, SE = .06–.08). More specifically, scientists agreed more with the statements that their "colleagues participate in this type of public engagement regularly" (M = 3.67–4.23, SE = .08) and "this type of public engagement is commonly practiced by my colleagues" (M = 3.65–4.19, SE = .08). We also asked three questions regarding subjective norms. The results showed that scientists were more likely than communication scholars to believe that scientists' "colleagues would respect someone who participates in this type of public engagement" (M_{comm} = 4.70, SE_{comm} = .07; $M_{scientist}$ = 5.18–5.36, $SE_{scientist}$ = .06–.07) and less likely to believe that scientists' "colleagues do not approve of this type of engagement" (M_{comm} = 3.29, SE_{comm} = .08; $M_{scientist}$ = 2.39–2.66, $SE_{scientist}$ = .06–.07). In other words, communication scholars were more likely to believe that scientists look down on scientists who communicate than scientists themselves.

To answer RQ3, we asked both scientists and communication scholars a series of questions about public engagement efficacy (Table 2). The results showed small differences between the three science communities but bigger differences between scientists and communication scholars. In general, communication scholars saw more challenges for scientists than scientists saw for themselves. For example, communication scholars were more likely to say that they believe "public engagement is difficult for most scientists" (M_{comm} = 5.35, SE_{comm} = .06; $M_{scientist}$ = 3.23–3.70, $SE_{scientist}$ = .08–.09) and were also more likely to indicate that they believed that "most scientists don't think [face-to-face] public engagement can make a difference in society" (M_{comm} = 3.89, SE_{comm} = .07; $M_{scientist}$ = 2.02–2.21, $SE_{scientist}$ = .06–.07). Scientists were also more likely to agree that "most scientists are skilled at [face-to-face] public engagement" ($M_{scientist}$ = 4.20–4.71, SE = .08–.09) than communication scholars (M_{comm} = 2.34, SE = .06). The differences between scientist groups were minimal, except that scientists from the biological society were slightly less likely to believe that scientists are skilled ($M_{Biological}$ = 4.20, SE = .08) at public engagement compared to the other two societies ($M_{General}$ = 4.65, $SE_{General}$ = .08; $M_{Geophysical}$ = 4.71, $SE_{Geophysical}$ = .09).

We asked both scientists and communication scholars a series of questions about their views on the public's attitudes toward science (RQ4; Table 2). Both scientists and communication scholars reported a positive belief in the public—that they "have reasonable expectation of science's ability solve problem"—and no significant group differences were found, $F(3, 1425) = .65$, n.s. Although significant differences were observed between the communication scholar group and each science society on statements that the public "has little knowledge about science," "treat scientists with respect," and "listen to what scientists have to say," the mean difference is rather small. The similar

Table 2. Scientists' and communication scholars' view on comparison (7-point scale).

	Communication scholars		General society		Geophysical society		Biological society		*F* (significance)
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	
View on social norm …									
Scientists' (my) colleagues participate in this type of public engagement regularly	2.68[a]	.07	3.92[c]	0.08	4.23[b]	.08	3.67[c]	.08	77.40**
This type of public engagement is commonly practiced by scientists' (my) colleagues	2.71[a]	.07	3.88[c]	0.08	4.19[b]	.08	3.65[c]	.08	67.95**
I think scientists' (my) colleagues would respect someone who participates in this type of public engagement	4.70[a]	.07	5.33[b]	0.06	5.36[b]	.07	5.18[b]	.06	20.57**
Scientists' (my) colleagues do not approve of this type of public engagement	3.29[a]	.08	2.53[bc]	0.07	2.39[b]	.08	2.66[c]	.07	30.95**
Generally speaking, scientists (I) care what their (my) colleagues think about this type of public engagement	4.60[a]	.08	4.23[b]	0.08	4.16[b]	.09	4.20[b]	.08	6.66**
Views on scientists' efficacy …									
Most scientists are skilled at this type of public engagement	2.34[a]	.06	4.65[b]	0.08	4.71[b]	.09	4.20[c]	.08	230.15**
This type of public engagement is difficult for most scientists	5.35[a]	.06	3.23[b]	0.09	3.33[b]	.10	3.70[c]	.08	151.46**
Most scientists do not have the time to communicate effectively with the public about their research	4.60[a]	.08	3.23[c]	0.08	3.67[b]	.09	3.70[b]	.08	48.38**
Most scientists wish they had more time to communicate with the public	4.28[a]	.07	4.83[c]	0.07	5.24[b]	.07	5.00[bc]	.07	32.65**
Most scientists do not think this type of public engagement can make a difference in society	3.89[a]	.07	2.09[b]	0.06	2.02[b]	.07	2.21[b]	.07	182.43**
This type of public engagement is probably a waste of scientists' time	2.10[a]	.06	1.78[b]	0.05	1.95[b]	.06	2.12[b]	.06	7.99**
Most scientists became a scientist to work for the public good	4.38[a]	.08	4.84[bc]	0.08	4.68[ab]	.09	5.00[c]	.08	10.90**
Most scientists are currently trying to make a positive impact on the world through their science	5.29[a]	.07	5.81[b]	0.06	5.84[b]	.06	5.86[b]	.06	19.28**
View on the public …									
Have reasonable expectation of science's ability to solve problems	4.46	.07	4.57	0.07	4.56	.08	4.48	.07	0.65
Have little knowledge about science	4.59[a]	.08	4.86[bc]	0.07	4.66[ab]	.07	5.06[c]	.07	8.45**
Treat scientists with respect	5.72[ab]	.06	5.88[a]	0.05	5.70[ab]	.06	5.65[b]	.06	3.42*
Listen to what scientists have to say	5.33[ab]	.06	5.48[a]	0.05	5.36[ab]	.06	5.21[b]	.06	4.06**

SE: standard error; HSD: honestly significant difference.
N_{comm} = ~362, $N_{Geophysical}$ = 307, $N_{general}$ = 373, $N_{Biological}$ = 372. Superscript letters "a, b, c" indicate group comparison from post hoc test (Tukey's HSD).
*$p < .05$; **$p < .01$.

mean, at least one point above midpoint (M=4.59–5.88), reveals that both scientists and communication scholars agreed that the public knows little about science but has respect for scientists and are willing to listen to what scientists have to say.

Communication objectives

The results showed that scientists and communication scholars shared similar opinions when it came to prioritizing communication objectives (Table 3; RQ5). All of the objectives listed were rated above the midpoint (7-point scale) by both scientists and communication scholars (despite being reminded that not all objectives can be a high priority). Of the objectives we asked respondents to prioritize, "help[ing] to inform people about scientific issues" was prioritized most heavily by communication scholars (M_{comm}=5.84, SE=.06) and even more by scientists ($M_{scientist}$=6.07–6.22, SE=.05). The next most prioritized objective was "getting people interested or excited about science" (M_{comm}=5.53, SE_{comm}=.07; $M_{scientist}$=5.90–5.97, $SE_{scientist}$=.05–.07). "Showing the scientific community's expertise" was rated as the lowest prioritized objective (M_{comm}=4.52, SE_{comm}=.08; $M_{scientist}$=4.61–4.80, $SE_{scientist}$=.07–.08). However, scientists believed that "defending science from those who spread falsehoods" to be the third most important objective ($M_{scientist}$=5.62–5.80, SE=.07–.08), while communication scholars prioritized "showing that the scientific community cares about society's well-being" (Scholar: Rank 3 vs Scientist: Rank 4) and "demonstrating the scientific community's openness and transparency" (Scholar: Rank 4 vs Scientist: Rank 5) more highly, while scientists all found "defending science from those who spread falsehoods" more important than the other two objectives (Scientist: Rank 3 vs Scholar: Rank 5).

Communication scholars' involvement

We asked communication scholars to evaluate the amount of effort they devote to training scientist groups (RQ6). The results showed that more than half of the respondents had spent no time training scientists (62%), science/health regulators (64%), or medical/health personnel (57%) over the past year, and the rest devoted a very small amount of time to it. On the other hand, a non-negligible number of the scholars also reported spending a substantial amount of time conducting training related to science communication. However, more than half (58%) of the respondents have trained scientists to communicate with journalists/communication professionals, and much more with informal training through involvement in activities like review panels and organizational boards. Only 26% of respondents indicated that they had spent no time devoted to this activity (Table 4).

We also asked communication scholars who had spent time in training to evaluate the focus of their training. Very few of them indicated that any one focus was the sole focus of training (1%–6%). The results showed that "engaging the public/citizens in dialogue/debate" (40%) and "training in theories/models of communication" (34%) appeared to be the primary focus of training for more than a third of communication scholars, while almost a half of them (42%) said that "being interviewed by media" is not a focus of training. Communication scholars were more varied in their other training foci, with some emphases on topics such as "understanding news values/norms," "public speaking/making public presentations," and "writing for the public/media" (Table 5).

5. Discussion

The current study was developed based on the idea that communication scholars—especially those who have worked on issues related to science, health, and risk communication—may have insight that would be valuable to discussions about how to ensure more and higher quality participation in

Table 3. Scientists' and communication scholars' view on communication objectives.

	Communication scholars			General society			Geophysical society			Biological society			*F* (significance)
	M	*SE*	*R*	*M*	*SE*	*R*	*M*	*SE*	*R*	*M*	*SE*	*R*	
Helping to inform people about scientific issues	5.84[a]	.06	1	6.20[b]	.05	1	6.22[b]	.05	1	6.07[b]	.05	1	10.16**
Getting people interested or excited about science	5.53[a]	.07	2	5.97[b]	.06	2	5.90[b]	.07	2	5.94[b]	.05	2	11.42**
Showing that the scientific community cares about society's well-being	5.42[a]	.07	3	5.69[b]	.06	4	5.44[a]	.07	4	5.71[b]	.06	4	5.97**
Demonstrating the scientific community's openness and transparency	5.36	.07	4	5.47	.06	5	5.36	.07	5	5.56	.06	5	2.31
Defending science from those who spread falsehoods	5.32[a]	.08	5	5.76[b]	.07	3	5.62[b]	.08	3	5.80[b]	.07	3	8.49**
Framing research implications so members of the public think about a topic in a way that resonates with their values	5.09	.08	6	5.25	.07	7	5.24	.08	6	5.30	.07	6	1.45
Hearing what others think about scientific issues	5.01	.08	7	5.13	.06	8	4.89	.08	8	5.10	.07	8	2.29
Showing that scientists share community values	4.90[a]	.08	8	5.29[b]	.06	6	5.00[a]	.08	7	5.27[b]	.07	7	7.54**
Showing the scientific community's expertise	4.52[a]	.08	9	4.80[b]	.07	9	4.68[ab]	.08	9	4.61[ab]	.07	9	2.69*

SE: standard error; *R*: ranking; HSD: honestly significant difference.
$N_{comm} = \sim 362$, $N_{Geophysical} = 307$, $N_{general} = 373$, $N_{Biological} = 372$. Superscript letters "a, b, c" indicate group comparison from post hoc test (Tukey's HSD).
*$p < .05$; **$p < .01$.

Table 4. Communication scholars' engagement in training different groups.

	No time	<1 week/ year	~1 week/ year	~2 weeks/ year	~3 weeks/ year	>3 weeks/ year
Bench scientists or engineers	62%	17%	7%	5%	2%	8%
Science/health regulators	64%	19%	9%	4%	1%	2%
Medical/health personnel	57%	17%	8%	4%	2%	11%
Journalists/communication professionals	42%	25%	11%	7%	2%	13%
Informal training through involvement in activities such as review panels and organizational boards	26%	23%	18%	16%	8%	9%

Table 5. The focus of communication scholars' training.

	Sole focus of training	Primary focus of training	Secondary focus of training	Minor focus of training	Not a focus of training	*N*
Being interviewed by media	3%	14%	14%	28%	42%	140
Understanding news values/ norms	2%	23%	26%	25%	25%	138
Public speaking/making public presentations	4%	27%	22%	26%	21%	139
Engaging the public/citizens in dialogue/debate	6%	40%	23%	18%	14%	139
Writing for the public/media	1%	28%	23%	22%	26%	141
Training in theories/models of communication	3%	34%	20%	20%	24%	143

public engagement activities by scientists. While a number of studies have investigated how scientists and communication scholars perceive scientists' communication abilities, the current study directly compared potentially meaningful differences in the views of these two groups. The findings on the differences between scientists and communication scholars provided empirical evidence to what was suggested in the most recent National Academy of Science report about effective science communication, which illustrates that bridging this gap between researchers and practitioners of science communication is essential to improving public engagement (National Academies of Sciences, Engineering, and Medicine, 2017). It is necessary to build a coherent science communication enterprise in order to make reasonable decisions on effective science communication.

First, the results regarding scientists' past behaviors and communicators' expectations (RQ1) suggest that communication scholars expect more public engagement from scientists than what scientists actually perform, especially when it comes to online engagement where regular activity can be important for building and developing relationships with potential audiences. This should not be surprising as it is consistent with findings from the Pew Research Center that indicate less than half of the general society scientists reported that they "often" or "occasionally" engage with the public (Rainie et al., 2015).

Regarding predictors of engagement activities, the scientists surveyed generally appeared to have more positive views than communication scholars about factors that likely affect engagement behavior. First, both scientists and communication scholars shared similar opinions about the

degree to which the public respects and listens to scientists, but scientists were somewhat more likely to indicate that they believed that the public has little knowledge about science. Although the science community and communication scholars have positive impressions of the public, this finding also reflects a potential reason why scientists are likely to hold a deficit model perspective that seems them focus mostly on educating or informing the public during science communication (Frewer et al., 2003). Second, scientists see the science community's norms as more positive in regard to public engagement than communication scholars. The findings might signal that communication scholars may underestimate the normative support scientists perceive from colleagues when they engage and thus tend to over-emphasize normative concerns in training and discussion. Last, scientists appear to disagree with communication scholars on whether their engagement efforts are likely to be well-done and successful. One likely explanation could be that communication experts are more critical toward communication efficacy because of their proximity to the subject. Scientists may also suffer from optimistic bias.

Scientists and communication scholars appear to view communication objectives somewhat similarly. Both groups prioritize knowledge-based objectives, reflecting the mainstream tendencies of science communication. Demonstrating the scientific community's expertise is the least prioritized objective by both scientists and communication scholars. One noteworthy difference is that communication scholars prioritize "showing that the scientific community cares about society's well-being" higher than scientists. This finding likely highlights the emphasis science communication scholars have placed on the importance of relationship building through two-way scientist–public dialogues (Nisbet and Scheufele, 2009), as well as storytelling where scientists are able to play the role of a protagonist solving important and challenging problems (Olson, 2015).

Although it is not the focus of the current study, RQ6 showed the connection between scientist from science majors and communication scholars who study science, health, risk communication, and related topics. The finding indicates that communication scholars may have less direct contact with scientist communicators but more indirect interaction with journalists or informal involvement in activities. With regard to the focus on training, engaging the public/citizens in dialogue/debate is the most common focus, and basic communication theories and models are also a regular focus. An interview study with science communication trainers, however, showed that trainings are commonly focused on practical skills and less on theoretically focused topics (Besley et al., 2016). Few of the trainers interviewed in that study were communication professors, however, and future studies may therefore need to find ways to assess why there may be differences in the views of communication scholars and the training community. Future studies should also expand on the types of theoretically focused topics that should be integrated into science communication training curricula.

Limitations and future study

The current study attempts to identify differences between how science communication scholars and the science community think about public engagement. While the current study focused on the descriptive results and comparisons, future research can explore the relationships between factors to further understand the potential origins of these differences. Moreover, few studies have examined this issue with scientists from multiple disciplines or different countries, and the current study only selected three science societies to represent the natural science community in the United States. Although our findings show little difference between these societies, the relatively low response rate may affect the generalizability of the findings. There is the possibility that scientists from other types of societies or other countries might respond differently. Future research should therefore explore the views of members from other disciplines such as health or scientists from other countries on their perceptions of public engagement. In addition, it is possible that scientists and communication scholars who had previous engagement or training experience were more

likely to participate in the survey; we acknowledge that there might be non-response bias, which may lead to overestimation of scientists' engagement perception and behavior in the scientist population overall.

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