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Two-way communication between scientists and the public: a view from science communication trainers in North America

Shupei Yuan[a], Tsuyoshi Oshita[a], Niveen AbiGhannam[b], Anthony Dudo[c], John C. Besley[a] and Hyeseung E. Koh[c]

[a]Department of Advertising and Public Relations, Michigan State University, East Lansing, MI, USA; [b]Department of Civil, Architectural and Environmental Engineering, The University of Texas at Austin, Austin, TX, USA; [c]Stan Richards School of Advertising & Public Relations, The University of Texas at Austin, Austin, TX, USA

ABSTRACT

The current study explores the degree to which two-way communication is applied in science communication contexts in North America, based on the experiences of science communication trainers. Interviews with 24 science communication trainers suggest that scientists rarely focus on applying two-way communication tactics, such as listening to their audiences or tailoring messages based on their audiences' needs. Also, although trainers generally recognize the value of two-way communication, it is seldom addressed in science communication trainings. The importance of two-way communication in fostering interactive dialogical communication between scientists and the public, and thus the importance of emphasizing it more during science communication training, is discussed.

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Introduction

In recent years, a growing portion of the scientific community has been focused on improving the quantity and quality of science communication (Cicerone, 2006; Holt, 2015; Leshner, 2007). A 2015 US-based survey, conducted by the Pew Research Center and the American Association for the Advancement of Science (AAAS), revealed that scientists highly value outward-facing communication. The large-scale survey, which targeted AAAS member scientists in the U.S., showed that almost all of the respondents (98%) had had some level of interaction with the public about science and research (Rainie, Funk, & Anderson, 2015). The survey also found that about half of these scientists (47%) used social media, and nearly a quarter (24%) wrote a blog in order to communicate with ordinary citizens about science (Rainie et al., 2015). Results from this Pew/AAAS survey dovetail with other recent research efforts in the U.S. (e.g. Besley, Oh, & Nisbet, 2013; Nisbet & Scheufele, 2009) and around the world (Burchell, 2015) showing that public communication is becoming a growing priority for scientists.

As the prioritization of science-public communication evolves, its primary purpose is also shifting. For instance, Burns, O'Connor, and Stocklmayer (2003)' identified several objectives relevant to contemporary science communication, including awareness, enjoyment, interest, opinion formation, and understanding. Those objectives resonate with recent conceptual and theoretical research efforts on science communication that have reframed traditional models anchored in one-way knowledge transfer from experts to non-experts into more fluid bi-directional models. These efforts have attempted to reorient the nature of science communication toward two-way engagement that

CONTACT Shupei Yuan syuan@niu.edu Department of Communication, Northern Illinois University, DeKalb, IL, USA

seeks to build mutual understandings between science communicators and their publics (Bauer, Allum, & Miller, 2007; Irwin, 2008; Nisbet & Scheufele, 2009). Scientists, however, are only beginning to adjust to this new era of two-way science communication, and many of them are seeking the help of professional science communication trainers (Besley, Dudo, & Storksdieck, 2015). In this study, we apply the concept of two-way communication, which is used in the field of public relations (PR) to study the communication of organizations and their publics (Grunig, 2001; Grunig & Dozier, 2003; Grunig & Grunig, 1989; Grunig & Grunig, 1992; Grunig & Hunt, 1984), in the context of science communication in North America. The purpose of this exploratory study is to discuss the current state of affairs pertaining to two-way communication from the perspectives of North American science communication trainers.

Specifically, the current study focuses on the concept of two-way symmetrical communication, which emphasizes interactive communication and mutual understanding between two parties. Our underlying assumption is that the emphasis on two-way communication has the potential to improve how scientists think about and approach science communication. Therefore, we are interested in the extent to which North American science communicators may actively seek opportunities to learn about audience opinions, and the extent to which they are open about adjusting their communication styles based on feedback from their audiences. To answer these questions, we interviewed science communication trainers who have had regular interactions with North America-based scientists. In the following section, we present the rationale for our study by reviewing previous literature related to science communication and training, as well as literature from relevant PR scholarship.

Science communication activity and trainings

Scientists play a central role as communicators in public engagement activities. As the Pew/AAAS survey indicated, about 87% of scientists support active engagement in public policy debates (Rainie et al., 2015). Scientists participate in science communication activities for multiple reasons, including professional responsibility (Gascoigne & Metcalfe, 1997), as well as personal enjoyment (Dunwoody, Brossard, & Dudo, 2009). There are several ways in which scientists can participate in such externally focused communications, including direct interactions (i.e. face-to-face), online conversations, and communications through media professionals (i.e. mediated communication). Moreover, scientists' public communication engagement levels also vary. In recent years, science communication scholars have identified a handful of factors that are consistently associated with scientists' level of engagement. For example, one study conducted across five different countries found that the relationship between the scientific community and the media can improve engagement (Peters, Brossard, et al., 2008). Other personal factors such as the scientist's own communication self-efficacy are also commonly linked to engagement (Besley et al., 2013; Dudo, Kahlor, AbiGhannam, Lazard, & Liang, 2014; Dunwoody et al., 2009). In another US-based survey, Dudo (2012) also identified perceived self-efficacy as one of the major factors that predict scientists' public engagement.

Given the importance of self-efficacy in driving scientists' public engagement behaviors, it is encouraging that there is a growing number of science communication training programs or workshops that aim at helping scientists become more effective communicators when engaging with the public (Smith et al., 2013). In the current study, we broadly define science communication training as any activity that provides guidance to members of the scientific community regarding how to communicate more effectively with the public about scientific issues. In the U.S., scientific institutions have started making efforts to provide scientists with training resources or guidelines in order to aid their interactions with the media (Peters, Heinrichs et al., 2008). Unfortunately, however, it is still uncommon for North American graduate degree programs in physical and life sciences to offer such communication trainings as part of formal course requirements (Brownell, Price, & Steinman, 2013). Prominent examples of science communication training in the U.S. include the Alan Alda Center for Communicating Science at Stony Brook University and the AAAS Center for Public

Engagement with Science, which both provide expansive training programs to help scientists become better communicators.

Such trainings often focus on topics such as developing media relations skills and practicing effective knowledge transmission (Dudo, 2015). Beyond the U.S., however, we sometimes find training programs that integrate more thorough communication modules. For instance, the European Science Communication Network uses capacity building such as public dialogue development and controversy identification, along with skill training in their trainings (S. Miller, Fahy, & The ESConet Team, 2009). Also, in Australia, several studies have investigated the integration of science communication into university science education (Edmondston & Dawson, 2014; Edmondston, Dawson, & Schibeci, 2010; Mercer-Mapstone & Kuchel, 2015). Although training is still not part of the formal curriculum (Edmondston & Dawson, 2014), students are encouraged to build their capacities to communicate, such as through identifying a target audience (Mercer-Mapstone & Kuchel, 2015).

Additionally, empirical assessments of the specific objectives and goals that science communication trainers have for their trainings are still limited. One of the few studies on this topic (Besley, Dudo, Yuan, & Ghannam, 2016) found that trainers mostly focus on teaching communication skills that help scientists communicate information and build knowledge, which is consistent with other findings regarding the scientific community's approach to public communication (Bauer et al., 2007; Besley & Nisbet, 2013). A problem with this approach is that other objectives, including fostering excitement, building trust, and reframing issues were overlooked as a means of achieving scientists' long-term goals in their training programs. On its own, one-way communication is not effective at achieving many communication objectives (Longnecker, 2016). Therefore, the purpose of this study is to explore the current status of North American science communication and related trainings from the perspectives of communication trainers. We specifically explore the extent to which two-way communication is applied in science communication trainers' curricula in North America. In the current study, we define trainers as those who design or conduct any kind of science communication training activities full time or part time.

Theoretical background

Previous science communication researchers have linked science communication to PR in that 'science journalism is highly dependent on scientists and organizational science PR' (Peters, Heinrichs, Jung, Kallfass, & Petersen, 2008, p. 75). The current study also looks at using a PR approach to achieve effective science communications. Grunig and Hunt (1984) proposed the *excellence theory* to describe how best practices in PR can make organizations more effective. The theory explains that PR should function as a boundary spanner between organizations and its publics (Grunig, 2001; Grunig & Dozier, 2003; Grunig & Grunig, 1989; Grunig & Grunig, 1992; Grunig & Hunt, 1984). In doing so, it built upon Grunig and Hunt (1984) four models of PR: press agentry, public information, two-way asymmetric, and two-way symmetric.

This focus on two-way communication reflects a contemporary approach to effective communication. Organizations looking to apply the above models need to comply with various tasks. For instance, while the first two models require that organizations only convey messages to their publics, the third model (the 'two-way asymmetric' model) suggests that organizations seek information from the public along with providing information to that public, and the fourth model (the 'two-way symmetric' model) suggests that organizations encourage key publics to voice their opinions either to resolve conflict and/or to promote mutual understanding between the two entities (Grunig & Hunt, 1984). Although the last two models can potentially provide a channel through which public opinions are sought, the last model (the 'two-way symmetric' model) is the one that allows organizations to achieve excellence by helping them and their publics to meaningfully understand each other and develop mutually beneficial relationships (Hon & Grunig, 1999).

However, there is sometimes a gap between how two-way symmetrical communication is viewed and practiced by parties on both ends of communication exchanges. Previous research has pointed

out that while organizations often believe that they are providing opportunities for such communications to occur, the public is not always aware that such opportunities exist (Huang, 2007). Therefore, engaging individuals and organizations with two-way communications is not always straightforward and well understood. Two-way communication also requires communicators to obtain certain interactive writing and engagement skills (Anderson, Swenson, & Gilkerson, 2016). This challenge potentially exists between science communicators and the public as well. To help us understand the extent to which scientists use such bi-directional communication techniques when engaging with non-experts, we inquire about their exposure to such techniques in science communication trainings. Specifically, we examine the extent to which training includes an explicit focus on (1) identifying and listening to specific audience needs and concerns, and (2) responding to audience needs and concerns.

Applying two-way approach in science communication

The value of two-way communication in scientific contexts lies in its potential to build favorable relationships between science experts and non-experts. The significance of such relationships has long been highlighted in academic critiques eschewing top-down linear communications that are governed by the 'knowledge deficit model' of science communication (Sturgis & Allum, 2004). This traditional model presumes that the irrational and inaccurate beliefs about science are derived from deficits in scientific knowledge. Therefore, if science literacy increases among the public, according to the deficit model, the public will be supportive toward science (J. D. Miller, 1983, 1998). However, years of science communication research have indicated the replacement of the old knowledge deficits model with a 'science in society' model, which highlights the value of meaningful bi-directional communications between experts and non-experts (Casini & Neresini, 2013; Davies, 2008; Watermeyer, 2012).

Although the fields of PR and science communication both study-related concepts such as two-way communication, dialogical communication, and public engagement, only a small number of studies have explored the convergence between the two areas (e.g. Borchelt & Nielsen, 2014; Trench, 2008). For instance, a recent U.S.-based study examining the extent to which scientists think about their publics when communicating found that there is still a lack of consideration in issues such as building audience-focused communication, and designing understandable messages for the public (Besley et al., 2015). Another study discussing science engagement practices in the U.K. also highlighted the value of two-way dialogue (Jensen & Holliman, 2016).

In the present study, we are particularly interested in considering the PR concepts of two-way communication and dialogic communication within science communication. Two-way communication acts as the starting point to reach an improved relationship between scientists and the public. Dialogic communication occurs in two-way symmetric communication settings and involves relationship building among those involved in a communication (Kent & Taylor, 1998). Dialogic communication thus can be described as one type of relational interaction in two-way communication environments. Kent and Taylor (1998) defined dialogic communication as a product of two-way symmetrical communication (p. 323). Literature on dialogic communication largely supports the positive effects that relationship building can have on the effectiveness of persuasive messages (see a review: Yang, Kang, & Cha, 2015). In the context of science communication, dialogic communication is manifested in public engagement practices. However, as discussed above, such practices continue to be sparse and limited. Scientists and science organizations continue to practice one-way communication and underuse the interactive features of social media (Lee & VanDyke, 2015). Additionally, scientists continue to have a limited understanding of the public and their expectations (Besley, 2014). However, very few empirical studies have explored in depth how scientists perceive and practice dialogic communication. The current study therefore provides novel insights about how science communication trainers evaluate this issue.

There is also a limited focus in academic literature on science communication trainers' efforts in addressing two-way communication. It is also rare for studies to look at expert evaluations of the current state of affairs of science communication and science communication training. In fact, to our knowledge there is only one empirical study that has focused on science communication training in the United States (Besley et al., 2016). Some studies of science communication training efforts in Europe have found that training focuses mostly on transmitting scientific knowledge to the public (Trench & Miller, 2012) and emphasizes the importance of engaging with the publics quite minimally (Palmer & Schibeci, 2014), with very few exceptions (S. Miller et al., 2009). In other words, it appears that the main issue contemporary science communication training programs focus on most is building communication skills (e.g. clear writing, jargon-free speech, etc.).

Yet, there is some evidence suggesting that certain science communication experts or trainers have started to realize the merits of two-way communication. For example, one study that surveyed science communication experts (those who conduct research on science communication) showed that when they train scientists, they find it important to teach communication models and theories that explain communication as a two-way street (Besley & Tanner, 2011). Some other past work on public engagement training focuses on creating opportunities for dialogues between scientists and their broader communities (Nisbet & Scheufele, 2009).

The current study takes a bridging approach to study science communication and PR through focusing on two-way science communication in public engagement. For this purpose, we conducted in-depth interviews with science communication trainers to explore how they perceive science communication in its current practice, as well as the steps they take to promote two-way communication. Given the inherently exploratory nature of the study, we sought to address two research questions:

RQ1: To what extent do science communication trainers perceive that the scientists they train are interested in performing – or already performing – two-way communication with the general public?

RQ2: To what extent do science communication trainers seek to help scientists achieve two-way communication with the general public?

Method

Sample

In the current study we define science communication trainers as people who design or conduct any kind of communication training for scientists. Following this definition, the research team started with an initial list of science communication training organizations and then used a snowball sampling method to compile a list of science communication training organizations. As an initial attempt of this research topic from a qualitative approach, we recruited trainers in the U.S. and Canada. In each organization, including both professional science communication training centers and university programs, we collected the contact information of one to two trainers who conduct regular ongoing science communication trainings. We sent one email that described the project and invited them to participate, as well as two follow-up emails and a phone call to solicit participation from those who did not response. Fifty-one trainers were contacted via email and 24 agreed to be interviewed. Interviewees were from universities, science societies, or private commercial or non-profit organizations. The sample consisted of 16 females and 8 males, and the average age of the trainers was 45 ($SD = 13$). Most interviewees reported being White ($n = 22$), one interviewee indicated his/her ethnicity as Asian/Indian, and another as African American, one respondent further identified as Puerto Rican. Most interviewees had completed a graduate school degree ($n = 19$), and a science background (e.g. biology, engineering) ($n = 15$). Table A1 includes the detailed individual profiles of the interviewees.

Interview procedure

We developed a semi-structured interview protocol with questions about the ways by which science trainers (1) evaluate scientists' communication practices, and (2) emphasize two-way communication skills (listening to the audiences, building trust, etc.) in their training programs. Additional questions focused on another set of research questions were also asked and reported in another paper from the research team (Besley, Dudo, Yuan & AbiGhannam, 2016). Interviewees were also asked to sign a consent form and provide background information through an online questionnaire. A phone interview was then conducted with each interviewee individually. Interviews ranged from 20 to 70 minutes with an average length of 42 minutes. All interviews were recorded and transcribed for further analysis. Interviews were conducted between September and November 2014.

Coding

Researchers coded all transcripts based on thematic analysis (Braun & Clarke, 2006), where the purpose is to find commonalities among the interviewees. The first and second authors identified a series of codes that emerged from the interview protocols, such as 'listening to the audiences,' and 'two-way training'. Then, they coded one manuscript together and discussed the agreement on each code. After reaching consensus on the coding scheme, the two authors coded the rest of the transcripts separately and then compared their findings and merged themes, as we present below (Guest, MacQueen, & Namey, 2011). The analysis here focuses on two aspects: the degree to which trainers viewed the pattern of scientists' communication activities to be two-way, and the trainers' efforts to emphasize two-way communication when training scientists. In the following section, we present the major findings with illustrative quotations.

Results and analysis

Interviews suggest that scientists are actively engaged in different types of science communication activities. However, trainers perceive scientists to communicate about their work mostly to 'educate' or 'share their knowledge' with the public, which we interpreted as one-way communication. Also, many trainers tended to emphasize building personal communication skills more than teaching the concept of two-way communication. This section explains those findings in detail. First we will discuss how science trainers view scientists' public communication, particularly focusing on the extent to which they believe scientists are performing two-way communication (RQ1). Then, we will report the extent to which communication trainers emphasize two-way communication in their training (RQ2). A summary of the findings and frequencies can be found in Table A2.

Trainers' evaluations of scientists' communication performance

Trainers reported that scientists attend communication training because they perceive public communication as opportunities to give back to society as well as something that can contribute to their professional development, including the potential for receiving tangible results (e.g. funding, hiring, promotion).

Active engagement in public communication activities

Most trainers shared the view that their client scientists are willing to engage in public communication activities. One trainer explains this enthusiasm by citing a scientist's comment: 'Of course I'm going to interact with the public, isn't that what all scientists do?' (#1). Therefore, there is an understanding that the public communication of science is steadily becoming the norm in the scientific community. In fact, previous research has shown scientists' engagement with the public to be affected by organizational norms (e.g. Dudo et al., 2014). This culture is encouraging scientists to

take part in science communication behaviors. In fact, trainers reported that not only do scientists have positive intentions to participate in public communication of science, but that they are actually more engaged than ever in these activities. For instance, the same interviewee said: 'They [Many scientists] have already done a classroom visit, or they've gone out to the mall for Engineering Day, or Science Fair Day, or something like that' (#1). In fact, most trainers in the sample perceived scientists to have diverse opportunities to communicate with the public, which is why they believed many of them are currently involved in some kind of science communication activities.

This perception, however, was not unanimously shared by our entire sample as some trainers felt that scientists still do not support public communication. At times, those views are influenced by organizational settings. Science communication, in fact, is governed by complex interactions among members of the scientific community who are constantly shifting how they perceive science communication (France, Cridge, & Fogg-Rogers, 2015; Horst, 2013). We have found this to be the perception especially of trainers working with younger scientists. One trainer, who is a research fellow at a university in charge of training science students, said: '[We] found that not every student or attendee of a workshop is interested in continuing to communicate for the duration of their career' (#6). The views here can be explained in light of previous research done on self-efficacy and involvement in science communication activities (e.g. Besley, 2014; Dudo et al., 2014). In those cases, working with younger scientists or scientists-in-training who might have lower efficacy as scientists and/or as science communicators might have influenced trainers' perceptions of the level at which science communication has been integrated into the scientific culture. Additionally, science programs in universities are already busy, which leaves students with very little interest and time to pursue science communication (Edmondston & Dawson, 2014).

Considerations regarding the audience

We asked trainers about ways by which the scientists with whom they have worked had attempted at understanding their audiences. Interviewees generally indicated that scientists are often weak in this area. One trainer said that they are: 'not [doing] as much as they should' (#19). Trainers mentioned that scientists paid little to no attention to segment the public based on their different levels of understanding or interest related to science. For instance, one trainer said that scientists: 'generally think like either I'm talking to scientists or not talking to scientists' (#20), an indication that scientists lump all non-experts into one group. Another trainer ascribed the lack of such audience considerations to the idea that scientists are very self-focused, and they tend to think more about what they want to achieve when communicating rather than on what others would like to hear about. The trainer said:

> I think that's also coupled with just a lot of self-awareness, for individual scientists around their goals and what their own personal communication style is. And so, just basically spending a little time thinking through. (#23)

Trainers especially notice such trends when scientists fail to speak the language of their audiences and prefer to focus on technicalities that are difficult for non-experts to understand. For example, one trainer said: 'Lots of times, when we do a practice interview with a scientist, halfway through, you get the feeling they've forgotten who they're speaking to, they are just focusing on answering the question' (#10). This was a shared observation by many trainers and it is the reason why some of them believed that scientists' public communication efforts often fail. One trainer said:

> What is it that the audience wants? Where are they starting from?… I think that's something that people often forget, and I think that is, when I've seen scientists trying to communicate and failing by not doing as well as they could, I think that is one of the main reasons, because they don't know their audience. (#19)

Additionally, the interviewees suggested that not only do scientists fail to think about their audiences prior to communicating with them, but they also blame them for any perceived failures in the communication. Scientists usually attribute their failures as communicators to their audiences' lack of knowledge. This, in fact, is a very detrimental view for any communication effort. As one trainer said: 'They don't want to change their message at all for their audience. They just … They think

it's an audience failure that the audience isn't understanding their message. They don't think it's their failure to communicate better' (#22). Therefore, although trainers report that scientists mostly ignore audiences prior to communicating with them, they tend to steer their attention to the audiences afterwards, attributing any perceived failures to the lacking knowledge and interest of their audiences.

The overwhelming perception here, however, is that scientists do not consider the audience when communicating because they do not have the communication background and experience to do so, rather than because of an inherent lack of interest in the audience. In other words, scientists seemingly did not know how to translate their considerations of the audience into their communication activities. One trainer said: 'I think they probably think about the audience a lot. I think that sometimes it's a hard reflection process without having any of the education theory given to them in school' (#17). This scenario is important because it implies that this gap in communication is not done deliberately, but is rather the result of insufficient knowledge on – and training in – communication.

Communication objectives

Trainers perceived the major focus of scientists when seeking science communication training to be on how best to deliver their knowledge to the public. Seeking public inputs about science is not a priority to them. In other words, scientists tend to engage in communication behaviors in order to 'advocate' the knowledge of science. For instance, a trainer said: 'many of those people have a bit of an advocacy tone to them, that is, they want the public to know more about science, and to not be afraid of science and things like that' (#1). In effect, as mentioned in the previous section, when scientists communicate with their audiences, they mostly focus on delivering their technical knowledge without tailoring it specifically to fit their audiences' needs or understanding. Trainers believe this limits the efficiency and success of their communications.

Trainers, however, seemed to understand why scientists are not engaging in two-way communications. They attributed that to their lack of time and experience. With respect to time, some trainers pointed out that scientists are often busy and have very limited availability to dedicate to science communication. One trainer said: 'They don't have a lot of time to spend thinking about their audience before they launch into some sort of communication practice' (#23). Additionally, trainers pointed out to scientists' overwhelming lack of abilities and expertise in building and practicing two-way communication skills. For instance, as one trainer puts it:

> People who've had some kind of presentation training … who work in a science museum or whatever, those people I think definitely have more awareness. Most other people are coming at it from the angle of, 'I have a thing I want to say and so now, it's figuring out how to say it to people'. (#8)

Although no communication trainers explicitly mentioned that scientists were conducting two-way communication with the public, some reported that certain scientists, especially those who had some experience interacting with non-scientists, began noticing who they are communicating with and understanding the importance of engaging the public in science discussions. As a result, trainers believed that those who were subjected to circumstances in which they have more time or prior experience in science communication are more likely to undertake two-way communication techniques and to understand the value of such techniques.

Trainers' views on two-way communication in science communication training

About half of the trainers indicated that the focus of their training programs is to teach scientists practical communication skills rather than discussing the importance of two-way science communication. Skills such as message building/developing (e.g. #1), avoiding jargon (e.g. #4), and identifying audiences (e.g. #18) were some of the major topics discussed in science communication trainings. Other skills such as social media use (e.g. #5), understanding policy makers (e.g. #3), and professional etiquette (e.g. #3) were also mentioned by few trainers. Table A3 summarizes skills commonly emphasized in the interviews.

Value of two-way communication

Conversely, more than three quarters of the trainers also indicated that they recognize the importance of two-way communication in order to guarantee successful science communication practices. As one trainer puts it: 'A scientist who is going to communicate with a broader audience, and thinks that the only job is passing on information, is not likely to be terribly successful' (#12). Trainers thus believed that the current one-way advocacy-style communication needs to evolve into a model of mutual learning and understanding, and that they can have a role in this evolution. One trainer for instance said: 'we really want to shift scientists into thinking about their communication goals less as focused on spewing their science out and more thinking about how they can have mutual learning with their audiences' (#4).

As a result of this perceived capacity, trainers reported certain ways in which they had incorporated two-way communication aspects in their training. For example, some trainers mentioned talking to their clients about the need to understand their audiences, especially in terms of the level of their interest in and knowledge about the topic of the communication. Yet, despite the fact that all trainers agreed on the need to integrate skills on two-way communication into their training programs, the way in which they offered these skills to their clients varied. For example, the focus of communication training ranged from offering general recommendations to think about audiences, to providing specific tactics about how to listen to and engage with audiences. The majority of the trainers generally fell into the latter category. Trainers also reported working with their scientist clients on how to 'listen to' (e.g. #10), 'think about,' (e.g. #6), and even 'study' (e.g. #21) audiences. Moreover, trainers reported that an important portion of training is dedicated to helping scientists prepare for different types of audiences with different educational backgrounds, interests, or beliefs. One trainer explained the tactics used in training to emphasize such skills:

> We emphasize asking questions and being accessible. So, allowing the audience to ask questions of the researcher, how to answer those without becoming negative or defensive, how to build credibility. So we emphasize that quite a bit in our training. (#6)

Challenges

Despite their efforts, trainers often found it challenging to work with scientists on developing those particular skills. Trainers reported that scientists seemed uncomfortable with such practices, and at times, interpreted them as insincere and dishonest. For instance, one interviewee said:

> I think it moves from a mindset where you are working towards persuasion of your own personal outcome to manipulating your audience. And I think scientists need to be very careful. And there's a lot of work in communication that to me kind of blurs that edge between having your own goals and trying to affect the goals of your audience. (#11)

Particularly, trainers indicated that scientists are not comfortable with settings goals that center on 'policy agendas' (e.g. #6) or 'marketing' (e.g. #21) themselves or their research. Trainers reported that such discomfort appears especially when discussing two-way communication with their clients because scientists often interpret such efforts as potentially dishonest. Particularly unfavorable among scientists is the notion that scientists would learn about their audiences in order to better appeal to them. Despite efforts from the trainers to explain those tactics as necessary to communicate any idea, and their importance in promoting mutual understanding between scientists and their audiences, it is difficult to get scientists to accept these viewpoints. This finding resonates with earlier work on scientists' perceptions of two-way communication, that scientists are reluctant to use framing strategy when communicating with the public (e.g. Nisbet, 2009). The idea that scientists might actually learn something from those with whom they were communicating also did not appear to be a focus of training discussions.

Therefore, although trainers realize the importance of introducing two-way communication in science communication practices, they are still not fully integrating this notion into their training programs. They also believe that scientists' lack of time and/or experience when communicating

with the public is preventing them from practicing bi-directional communication. Moreover, when trainers try to discuss those topics in their training sessions, some scientists get uncomfortable. They believe that many scientists join science communication training programs mostly to build their technical communication/presentation skills rather than learning about how to build a dialogue with their audiences. Also, it appears that scientists still perceive efforts to learn about audiences as dishonest, which is a big hurdle for science communication trainers to confront.

Discussion and conclusions

The current study finds that science communication trainers recognize the importance of training scientists to use two-way communication. However, they do not all equally integrate those skills into their curriculums. Our interviews revealed that trainers view understanding audiences as a key to achieving effective two-way communication. However, it is evident to experienced communication trainers that scientists have limited baseline awareness or interest in two-way communication.

This study identifies two main tensions related to the application of two-way communication models in science communication. First, there seems to be a disconnect between the scientists' generally favorable attitudes toward public communication and their acquiring of the appropriate skills that will help them communicate with their audiences. Given that modern science communication often happens online (Allgaier, Dunwoody, Brossard, Lo, & Peters, 2013; Bik & Goldstein, 2013; Fahy & Nisbet, 2011; Van Eperen & Marincola, 2011), and that two-way communication skills are necessary for effective communication in those domains (Stokes, Roberts, Crowley, & McEwen, 2015), scientists who lack the skills and motivation to engage in real dialogues are unlikely to be communicating effectively. The second disconnect is evident in the finding that although trainers appear to recognize the importance of two-way communication, their integration of such communication skills into their trainings often appeared, at the time of the interviews, to be limited and inconsistent.

The findings of the current study also provide strong evidence of a gap between what scientists are doing and what they should be doing from the trainers' perspectives. What we found is that more than just recognizing this issue, trainers have already started to take steps to help scientists adopt two-way communication. However, it is more room for science communication trainers to develop strategic ways of training scientists on interactive dialogical communication. Thus, scientists are still in need of guidance on how to understand and listen to their audiences.

This study, however, also illuminates a broader problem in that scientists might not understand the conceptual and practical value of two-way communication. According to our interviewees, scientists still believe that learning about an audience with an agenda to appeal to that audience is unethical. One way in which trainers can overcome this barrier is may be by emphasizing how two-way communication skills can benefit both science education and science communication. Engagement in fact has been found to have profound abilities in promoting science communication and science education alike (McKinnon & Vos, 2015). Since scientists perceive the righteousness of effective science education (Besley et al., 2015), they might become more receptive of two-way communication if presented within that context.

The findings in this study also offer science communication trainers with a new venue to revisit and better design their training programs from a public relation standpoint. Although previous researchers (i.e. Bray, France, & Gilbert, 2012; Mercer-Mapstone & Kuchel, 2015) have acknowledged the importance of understanding and engaging audiences, our study also finds that those skills are not yet fully emphasized in science communication training due to many reasons from the trainers and the scientists. Therefore, looking forward, science communication trainers should focus their efforts on better integrating two-way communication skills into their training programs.

In sum, this study provides evidence regarding the absence of two-way communication within the science communication training context from the viewpoint of the trainers. The core findings highlight the need for training to emphasize the importance of two-way communication to scientists. More importantly, our study reveals an apparent gap in science communication training programs

in that they still mostly focus on building technical communication skills and are currently unable to translate their perceptions of the importance of two-way communications into their programs.

Limitation and future research

We acknowledge several limitations of the current study. First, we only recruited and interviewed trainers in North America, so it would be insufficient to generalize from these results. It is possible that trainers from other countries outside of North America might have different perceptions or training approach. Nevertheless, we have confidence that the findings still provide important insights to trainers in North America based on the consistency in participants' responses. The second limitation is that we only interviewed trainers about this issue on scientists' performance. It would be valuable to hear from scientists on how they think of trainers' two-way communication performance in future studies, in order to achieve a comprehensive understanding.

The current study used semi-structured interviews as an initial start to understand how U.S.-based science communication trainers evaluate scientists' activities and their own efforts in promoting two-way communication. To minimize the limits of self-report, future research should use complementary qualitative methods, such as observation or ethnographic research to more fully reveal the dynamics of science communication training programs, which may provide a more clear and objective picture of scientists' and trainers' performance. Future quantitative research is also needed to help with identifying the factors that influence scientists' two-way communication activities and how science communication training can help build those skills. Moreover, because of cultural differences, we expect that scientists in other countries may communicate with the public differently compared with scientists in the U.S. As part of future research plans, we will investigate this topic with science communication trainers based outside of North America to better understand their perceptions and training approaches.

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Appendix

Table A1. Interview subject biographies.

Interviewee 1 (Male, White, 50–60) has a Ph.D. in a humanities/social science field. He is currently working as a professor in a non-natural science field.
Interviewee 2 (Female, Non-white, 40–50) has a Ph.D. in the natural sciences. She is currently working on science communication consulting.
Interviewee 3 (Female, White, 30–40) has a bachelors in the natural sciences and a masters in social sciences. She is currently working as a public information specialist.
Interviewee 4 (Female, White, 30–40) has a master's in the natural sciences. She is currently working for a professional science society.
Interviewee 5 (Female, White, 30–40) has a Ph.D. in the natural sciences. She is currently working as a science communication trainer.
Interviewee 6 (Female, White, 30–40) has a Ph.D. in the natural sciences. She is currently a research fellow in a university.
Interviewee 7 (Female, White, 30–40) has a Ph.D. in the natural sciences. She is currently a post-doctoral fellow within a university and has run a science communication training program.
Interviewee 8 (Male, White, 20–30) is pursuing a Ph.D. in the formal sciences. He is currently a graduate student in a university and a science blogger.
Interviewee 9 (Feale, White, 30–40) has master's in the natural sciences. She is currently working part time for a science communication training organization.
Interviewee 10 (Male, White, 50–60) is trained in communication and has no specific science background. He is currently working as the owner of a communication training company that does science-focused workshops.
Interviewee 11 (Male, White, 40–50) has a bachelors in the natural sciences. He is currently involving in multiple roles including the founder of a training program.
Interviewee 12 (Male, White, 50–70) has a Ph.D. in the natural sciences. He is currently working as a university professor and director of a science center.
Interviewee 13 (Female, White, 50–70) has a master's degree in social sciences/humanities. She is currently working as a director for a science communication center that provides students-related courses.
Interviewee 14 (Female, White, 30–40) has a Ph.D. in the social sciences/humanities. She is currently directing a team of social scientists that conducts multi-method communication research.
Interviewee 15 (Male, White, 50–70) has a Ph.D. in the natural sciences. He is currently working as an administrator for a science organization at his university
Interviewee 16 (Female, White, 30–40) has a bachelors in natural sciences and a masters in the social sciences. She is currently working with multiple information science education institutions.
Interviewee 17 (Male, White, 50–70) has a bachelors in the social sciences. He is currently the leader of a strategic communication, branding and marketing consultancy.
Interviewee 18 (Female, non-White, 30–40) has a Ph.D. in the natural sciences. She is currently working as a manager of outreach in a university.
Interviewee 19 (Male, White, 30–40) has a Ph.D. in the natural sciences. He is currently working as a public outreach coordinator for a nature organization.
Interviewee 20 (Female, White, 30–40) has a Ph.D. in the natural sciences. She is currently working as a department director for a scientific society.
Interviewee 21 (Female, White, 50–70) has a bachelors in the natural sciences and master's degree in the social sciences/humanities. She is currently a director of PR and science communication.
Interviewee 22 (Female, White, 30–40) has a master's in the social sciences. She is currently a program manager for a science communication training source at a public organization.
Interviewee 23 (Female, 40–50) has a Ph.D. in science education. She is currently working as an outreach and education director for a federal government funded research center.
Interviewee 24 (Female, 50–60) has a Ph.D. in an interdisciplinary field. She is currently the founder and director of a science communication program.

Table A2. Summary of interview themes.

Themes	N*
Evaluations of scientists' communication performance	
Active engagement in public communication activities	10
Considerations regarding the audience	19
Communication objectives	18
Views on two-way communication in science communication training	
Values of two-way communication	11
Challenges	12

Note: N*: number of interviewees who mentioned about the theme.

Table A3. Summary of training skills.

Skills	N*	Examples
Building/developing a message	14	'I'm teaching them a message box. How to say what you want to say […]' (#1). 'Thinking carefully about the message that you're crafting, and so some of that is getting down to the main point, so what really matters in your work? […]' (#3).
Avoiding jargon	9	'We do have something on jargon, of wording jargon, but we don't talk about words that you should try and use to hook your audience, but rather words you shouldn't use in order to knock this in to your audience' (#2).
Identifying audiences	8	'[T]he skills are things like identifying who the audience is, the available audience, that you will be addressing. Then specifically, what is the target audience that you want or need most to influence. What is their current disposition and attitude toward your topic?' (#18)
Writing skill	6	'[T]he difference between writing a technical paper and presenting scientific information as a story' (#7). 'We have exercises or sessions or assignments where they have to write something' (#16).
Media interview	4	'[H]ow to talk with the media, and what to do to prepare for an interview, whether it's TV or radio or that sort of thing' (#3).
Public speaking	4	'[The skills I emphasize are] [S]peaking and reacting spontaneously, speaking with confidence, making a good connection with your audience, expressing your enthusiasm for your research, paying dynamic attention to what other people are saying, relaxing physically and mentally in front of an audience[…]' (#11).
Non-verbal communication	3	'[A] specific kind of communication skill, is using their non-verbal communication as well, so using body language and voice delivery, which some people don't typically think about as communication' (#10).
Use of social media	2	'We teach them Twitter as a hands on tool, so the actual practice of how to tweet, what the protocols and the nomenclature and all that sort of things are' (#5).
Working with policy makers	2	'[H]ow to reach out and work with a community group or policy makers. So things like, "How to call the leader of a community group and schedule a meeting or a presentation for that community group"' (#3).
Professional etiquette	1	'[T]hey go over more of the kind of stuff like, "Make sure you wear a suit and have business cards," and that sort of thing' (#3).

Note: N*: number of interviewees who mentioned about the skill.