

Microbiologists' Public Engagement Views and Behaviors †

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In this study, we present results from an extensive survey of US-based microbiologists (adults) to explore these scientists' perceptions and behaviors related to communicating their research. Specifically, we explored the frequency with which microbiologists engage in public communication, how they evaluate their public communication experiences, and the factors associated with their willingness to engage in face-to-face and online public communication in the future. Data from a multi-wave online survey suggest that microbiologists (N = 903) are somewhat frequent communicators who derive great value from their outreach efforts. The results further suggest that social and psychological drivers of future intentions to engage with the public are consistent with the Theory of Planned Behavior (TPB). Specifically, microbiologists with more positive attitudes toward engagement were more willing to partake in direct and online communication activities. Similarly, microbiologists who believe they possess communication skills are more willing than their less efficacious colleagues to do either type of outreach. Our results also indicate that more-senior and more-active researchers are more willing to participate in direct and online engagement. Implications for communication training are discussed.

INTRODUCTION

In her award-winning book, *Good Germs, Bad Germs: Health and Survival in a Bacterial World*, journalist Jessica Snyder Sachs details the history and pitfalls of the United States' war on germs (1). The book is an excellent example of how science—specifically microbiology—can be communicated to the public in a historically rich and factual narrative that is both accessible to nonscientists and gives voice to the scientists who are driving microbial research in the 21st century. Of course, the idea of making science accessible to nonscientists is not new; as Nobel Prize-winning physicist Erwin Schrödinger wrote in 1951, “If you cannot—in the long run—tell everyone what you have been doing, your doing has been worthless” (2). Decades later, the scientific community is working harder than ever to encourage scientists to become proactive, frequent, and

effective public communicators (3–7). Indeed, the current president of the American Association for the Advancement of Science (AAAS), Rush Holt, explains that “science needs the support of the society it serves” and that “communication and education among scientists, engineers, and the public must improve” in order to garner that support (8). Holt's contention echoes those frequently expressed by his AAAS predecessor, past president of the organization Alan I. Leshner (9–11). Similarly, Ralph Cicerone, former president of the United States' prestigious National Academy of Sciences (NAS), called on scientists to “do a better job of communicating directly to the public” (12). Numerous NAS committees have similarly called on those involved in communicating about science to take communication seriously (13, 14), as have many prestigious scientific committees in other countries around the world (15, 16).

The research on science communication suggests that these high-profile calls for more public communication have been heard, and that engagement is becoming a fairly common part of the practice of science at large (17, 18). For example, in a study of members of the AAAS, about 40% of the more than 3,700 scientists surveyed described their outreach activities (e.g., talking to citizens, talking to reporters, posting on social media, or blogging) as happening occasionally or often, which suggests some regularity (19). These findings have been echoed in similar studies of UK-based scientists (20, 21).

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Research on science communication also has identified a handful of factors that are commonly associated with scientists' willingness to engage with the public. Most evidence suggests that male scientists (22–24), older scientists (18, 25, 26), and more productive scientists (i.e., scientists with greater scientific status) (27, 28) are more likely to engage. However, such demographic factors are often more weakly related with engagement behaviors than are psychological factors. Specifically, scientists' willingness to partake in public engagement has been increasingly associated with the social and psychological variables conceptualized in the Theory of Planned Behavior (TPB) (29, 30). For example, recent science communication research anchored by the TPB has continually found that scientists are more likely to engage when they possess a sense of self-efficacy (18, 22, 27, 31, 32), positive attitudes toward engagement (27, 32, 33), and, in some cases, when they perceive positive social norms (32) relative to engagement.

But what is known about microbiologists and public engagement? Do their experiences as public communicators dovetail with these findings? Several survey-based studies suggest that scientists specializing in biology or medicine may engage relatively more often than colleagues in other scientific disciplines (18, 24, 34). However, insights about microbiologists as public communicators are qualitative and limited in scope. One anecdotal example of an active microbiologist communicator is Jonathan Eisen, a professor who studies the diversity of microbes and their ecosystems at the University of California, Davis. Eisen was listed as number 25 on *Science* magazine's "The top 50 science stars of Twitter," based on number of followers and overall presence on the popular micro-blogging platform (35). It appears Eisen has benefited greatly from his public engagement efforts. He states that his high-level engagement on Twitter has helped him connect with the public in meaningful ways, but also that it has had a positive impact on his career as a scientist, helping to attract top graduate students to his lab, garnering him two grants for science communication projects, and allowing him to demonstrate in federal grant applications his dedication to broader impacts through public outreach (35).

Eisen, of course, represents a particularly gifted and active communicator—an exemplar; he is not likely characteristic of the field. Still, there is evidence of a growing commitment to communication within the broader microbiology community. Several years ago, the Alfred P. Sloan Foundation funded an online community for scientists working in the field of indoor microbiology to share their projects, findings, etc. The purpose of the site, Microbiology of the Built Environment Network (microBEnet), managed by Eisen, is to foster communication and collaboration among researchers, build connections with researchers in related fields, and connect with the "general public, funding agency representatives, [and] government staffers" (www.microbe.net). To date, the site has generated more than 65 articles, news stories and mentions in the mass media, many quoting the scientists who are generating the research. In

one recent article, "Debunking Germophobia," featured in the online magazine *Buzzsaw*, UC Davis researcher David Coil echoed Jessica Snyder Sachs's (2008) call to combat the historic public-relations war against germs. "Over much of recent human history," he explains, "we've treated microbes as the enemy. If we can convey to people that, you know, they're not all bad and that we just need to learn to live with microbes instead of fighting against them, there's real value to public health and society in doing that" (36).

Kahlor and colleagues (37) provided what is, to our knowledge, the first empirical study that examined microbiologists and public communication. The researchers conducted semi-structured interviews with 79 US-based scientists who conduct indoor microbiological research. Their findings suggested that the majority of the microbiologists interviewed regard themselves as competent communicators, with more than three-quarters of the sample perceiving themselves as information sources for nonexpert audiences on topics related to indoor microbiology. Additionally, more than two-thirds of the sample also said that they are known for making their research understandable, and that they find it easy to explain their research. Kahlor and colleagues interpreted their results as encouraging, noting that microbiologists "demonstrate some of the baseline traits—namely interest and self-perceived aptitude—that will be necessary... to bolster their public communication efforts and raise the profile of indoor environmental research issues." They also highlighted the need for data that provide a fuller picture of microbiology in the public sphere, particularly microbiologists' perceptions and behaviors about communicating their research. That is what we present here: results from an extensive survey of US-based microbiologists through which we provide a clearer sense of the extent and execution of microbiologists' public engagement efforts. The analyses and results that follow are guided by three research questions:

1. RQ1. How frequently do microbiologists engage in public communication?
2. RQ2. How do microbiologists evaluate their public communication experiences?
3. RQ3. What factors are associated with a microbiologist's willingness to engage in face-to-face and online public communication?

METHODS

The data reported below were gathered from a multi-wave online survey of US microbiologists (adult). The survey was administered to scientists who, at the time of the study, were active members of a large, US-based professional society for microbiology. Using Qualtrics software and the Tailored Design Method (38), a total of 7,930 members of this society were contacted via email between October 26 and November 15, 2015. Of these, 1,111 respondents completed the survey for a response rate of 14%. The

current study is based on 903 of these respondents because they reported (a) holding at least one doctoral degree and (b) being employed by an academic or government institution (i.e., respondents who indicated that their primary employer was a corporation and/or private company were not included in the analyses reported here). To help bolster the response rate, a modest incentive structure was offered that donated \$100 to the society for every 100 respondents who completed the survey. The study's response rate is consistent with response rates associated with surveys of expert communities. SPSS v.24 was used to generate the descriptive and multivariate analyses reported in this study. Appendix I contains a full list of the survey questions and the corresponding indices used in analyses. The study and protocols complied with all relevant federal guidelines and institutional policies related to human subjects. The survey data reported here is part of a larger, multi-year effort to assemble similar data across scientific fields.

Surveying current members of this particular professional society enabled us to access current contributors to microbiological science. Researchers who responded to the survey were predominately in the biological and biomedical fields (97%) and received most of their recent funding from the National Institutes of Health (NIH). Consistent with the relatively high age of the sample ($M = 53.3$ years, $SD = 13.9$ years), most respondents were mid-career level or above (73%) and had published extensively. Survey respondents also were mostly Caucasian and liberal (only 21% reported being "very" or "somewhat" conservative). Our respondents were 45% female; 84% of the respondents identified as white (2% African American, 11% Asian, and 3% other), and 5% identified as Hispanic. Respondents typically took between 15 and 30 minutes to complete the survey.

The survey began with a definition of public engagement ("We define science public engagement as any time a scientist seeks to communicate about a scientific topic outside of a formal educational setting with nonscientists who are not friends or members of his or her family. For this project, we are only focused on public engagement with adults"), followed by questions about past public engagement (in the past year) and future willingness to engage. Respondents were then randomly assigned to questions in the context of face-to-face communication with adults ("discussed science with adults who are not scientists, e.g., giving a public talk or doing a demonstration") or online communication with adults ("online engagement through websites, blogs and/or social networks, e.g., Facebook, Twitter, aimed at communicating science with adults who are not scientists"). The remaining questions then focused on the independent variables: consumption of science news, attitude toward engagement, perceived efficacy regarding engagement, time constraints for engagement, normative pressure to engage, past training in engagement, identification with engagement, and goals associated with engagement. Past research has identified these variables as being associated with scientists' public communication efforts (18, 27, 31, 39).

The inclusion of attitude, normative pressure, efficacy, and time constraints is further recommended by the Theory of Planned Behavior. Consistent with prior research (29), norms were measured as descriptive (i.e., views of whether or not others do the behavior) and injunctive (i.e., views of whether or not others expect you to do the behavior). In line with past research, the following control variables were also measured: age, gender, number of publications, past behavior, and organizational credit (i.e., credit given by one's organization for public engagement).

RESULTS

We first asked microbiologists how often they engage in public communication (RQ1). Specifically, we asked respondents about the frequency with which they had communicated in the past year with the adult public via four platforms (i.e., modalities): face-to-face interactions, online platforms, interactions with media professionals ("interviews or briefings with a journalist or other media professional, e.g. from a newspaper, television, online news site, documentary film, etc."), and interactions with policymakers or government entities ("direct interaction with government policymakers, e.g., elected officials, government officials, lobbyists, etc."). At the aggregate level, approximately 23% of the respondents said they never engaged through any of these platforms. About 22% had engaged through one of the platforms, 24% had engaged through two, 16% had engaged through three, and 15% had engaged through all four of the activities.

Looking at each of the behaviors individually, as can be seen in Figure 1, nearly 48% of respondents had communicated with the public using an online platform and about 20% had done so six or more times. Fifty-nine percent had communicated with the public via face-to-face interaction and about 20% had done so six or more times. Approximately 42% of respondents had communicated with media professionals, but only about 6% had done so six or more times. Finally, about 31% of respondents had communicated with policymakers or government entities, while only about 7% had done so six or more times.

Beyond assessing microbiologists' levels of public engagement, we sought to explore their evaluations of their public engagement experiences (RQ2). We asked respondents to evaluate their overall experience with public communication on a scale from very negative to very positive. Their overall experience appears to be quite positive. As can be seen in Figure 2, just over 68% of respondents described their experience as positive or very positive and about 17% described it as somewhat positive. Approximately 12% described it as neutral, while just under 2% described it as somewhat negative and less than 1% described it as negative or very negative.

We also sought to identify factors that are associated with a microbiologist's willingness to engage in direct (i.e., face-to-face) and online public engagement (RQ3).

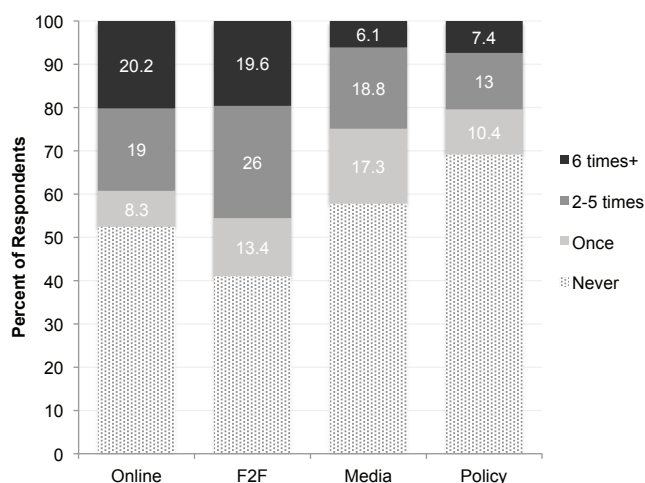


FIGURE 1. Microbiologists' frequency of engagement with the public between October 2014 and October 2015 (the last year prior to survey completion) via online platforms, face-to-face interaction, interactions with media professionals, and direct interactions with government/policymakers (n = 903).

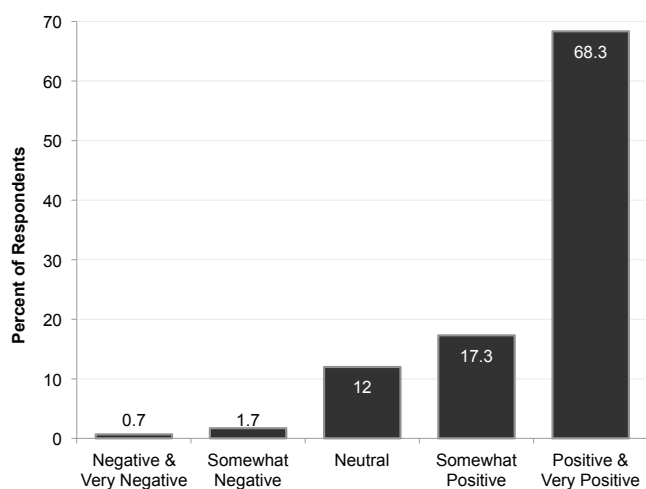


FIGURE 2. Microbiologists' evaluations of their overall public engagement experiences (n = 700).

To explore this research question, we used hierarchical ordinary least-squares regression analysis in which the independent variables were entered in blocks into the regression equation according to their assumed causal order (see Table 1). Our dependent variables were willingness to engage online and willingness to engage face-to-face, which we regressed separately. We focused on willingness to perform the behavior, because future intentions are commonly associated with actual behaviors (40), particularly for behaviors that are volitional (i.e., not habitual) and happen within changing contexts (41). Our regression model accounted for 35% of the variance in willingness to engage face-to-face with nonscientists, and 52% of the variance in willingness to engage online with nonscientists. Incremental contributions to the R^2 from each block suggest that the

control variables and Theory of Planned Behavior variables made the strongest contributions to willingness to engage either online or face-to-face.

Looking more closely at the first block, age was a significant contributor, with younger microbiologists more willing to engage both directly ($\beta = -0.32, p < 0.001$) and online ($\beta = -0.29, p < 0.001$), while gender was not a significant contributor in either case. Respondents' number of publications was a positive contributor in both cases ($\beta = 0.14, p < 0.01; \beta = 0.10, p < 0.01$), as was previous behavior ($\beta = 0.19, p < 0.001; \beta = 0.26, p < 0.001$). Organizational credit was not significant in either case. Neither of the variables in the second block—consumption of science news via online or traditional channels—were significant contributors to either direct or online engagement.

In the third block, the significant contributors to willingness to engage face-to-face were internal efficacy ($\beta = 0.19, p < 0.001$), external efficacy ($\beta = 0.10, p < 0.01$), attitude toward the behavior ($\beta = 0.15, p < 0.01$), descriptive norms ($\beta = -0.13, p < 0.01$), and injunctive norms ($\beta = 0.10, p < 0.01$). The contributors to willingness to engage online were internal efficacy ($\beta = 0.21, p < 0.001$) and attitude toward the behavior ($\beta = 0.26, p < 0.001$).

In the fourth block, only personal identity with engagement emerged as a significant contributor to willingness to engage in face-to-face outreach ($\beta = 0.13, p < 0.01$), while only the goal to convey the value of STEM was a significant contributor to willingness to engage in online outreach ($\beta = 0.09, p < 0.01$).

DISCUSSION

Our results indicate that microbiologists, as is the trend with other scientists (17, 18, 42, 43), are currently involved in public engagement activities and with some frequency. Furthermore, a large portion of the surveyed microbiologists have not only engaged in public communication activities, but also regard their outreach efforts as overwhelmingly positive and as something they intend to do more of in the future, which dovetails with other recent research (31, 43). We do not have data on whether this subjective positivity correlates with more objective measures of success related to audience outcomes; however, the extant research on scientific engagement suggests that scientists who do engage with the public often see the public as more friendly, receptive, informed, and eager to learn than those who do not engage (44). Our results also suggest that microbiologists may not encounter (or be particularly sensitive to) barriers that are traditionally seen as stark impediments to public communication, including a lack of time and internal support, concerns about inaccurate media depictions of their research, and negative feedback from their colleagues (45, 46).

Our sample did not have adequate numbers of international scholars to allow for a comparison between US and international scholars. We suspect that differences are likely to surface across cultures, given such factors as prestige;

TABLE I
Predicting microbiologists' willingness to participate in public engagement.

Dependent Variables: Two Pathways of Public Communication	Direct Engagement (Face-to-Face)	Online Engagement
Block 1: Control variables		
Age	-0.321 ^c	-0.289 ^c
Gender (male coded high)	0.034	-0.043
Status (number of publications)	0.143 ^b	0.101 ^b
Previous behavior (context-specific)	0.191 ^c	0.260 ^c
Organizational credit ("yes" coded high)	0.034	0.016
Incremental R ² (%)	18.4 ^c	34.9 ^c
Block 2: Consumption of science news		
Online-only media	-0.066	0.062
Traditional media	0.016	0.020
Incremental R ² (%)	0.30	3.70 ^c
Block 3: Theory of planned behavior		
Internal efficacy	0.194 ^c	0.206 ^c
External efficacy	0.102 ^b	0.008
Time for engagement	0.020	-0.038
Attitude	0.152 ^b	0.265 ^c
Descriptive norms	-0.126 ^b	-0.039
Injunctive norms	0.104 ^b	-0.011
Incremental R ² (%)	17.2 ^c	13.1 ^c
Block 4: Personal identity and goals		
Communication training experience	-0.073	-0.062
Personal identity	0.134 ^b	0.044
Goal: Improve STEM profession	0.025	0.035
Goal: Convey value of STEM	0.062	0.093 ^b
Goal: Enhance personal reputation	0.009	0.008
Goal: Fulfill a sense of civic duty	-0.017	0.051
Incremental R ² (%)	1.8 ^a	2.2 ^b
Adjusted R ² (%)	35.1	51.8
ANOVA	F ^{19,467} , 14.27 ^c	F ^{19,434} , 25.51 ^c

^a $p < 0.05$

^b $p < 0.01$

^c $p < 0.001$

This table depicts the results of hierarchical ordinary least-squares regression analysis in which the independent variables were entered in blocks into the regression equation according to their assumed causal order. Each column depicts the final model for each of the two dependent variables, showing which independent variables are significantly related to each dependent variable while controlling for the effects of all the other independent variables in the model. The cell entries in each column are standardized regression coefficients.

this is something that would be valuable to pursue in future research. In this study, we also focused only on academic and government scientists. This decision was based on the assumption that industry scientists are more likely to feel pressure within their organizations to have well-developed communication skills in order to communicate with non-scientists within the organization (47). This is certainly something that future research can attempt to validate.

Perhaps our more noteworthy findings are those that identify the individual-level variables related to a microbiologist's likelihood of engaging in public communication in the future. Overall, the results are largely consistent with the

Theory of Planned Behavior. This is particularly evident in the links between scientists' attitudes and self-efficacy and their behavioral intentions. Specifically, microbiologists with more positive attitudes toward engagement—measured via a multi-dimensional factor that captured feelings of enjoyment and usefulness—expressed being more willing to partake in direct and online communication activities. Similarly, microbiologists who believe they possess good communication skills are more willing than their less efficacious colleagues to do either type of outreach. However, external efficacy—the belief that engagement efforts are a productive use of time—was only positively associated

with microbiologists' willingness to participate in face-to-face engagement. Although the effects of external efficacy on engagement behaviors have not yet been widely tested (22), it may be that microbiologists associate their personal interactions with the public as being more impactful than similar efforts they make through online channels. Certainly, feedback received via face-to-face interactions can be more visceral and immediate than that which is typically received through a gadget. Regardless, microbiologists may be more willing to use online communication tools if the value and potential impacts of such efforts can be clarified to them.

The results associated with injunctive and descriptive norms are less clear. This is not necessarily surprising, given that norms—as compared with attitudes and self-efficacy—have been inconsistently linked with public engagement behaviors (48). Neither type of norm is associated with microbiologists' willingness to partake in online engagement. This may seem strange, but it is consistent with results from a recent study that also failed to find a relationship between norms and scientists' willingness to engage online (broadly) and through five different types of online communication (e.g., posting on social media, blogging, writing an online article) (22). It may very well be that beliefs about colleagues' engagement views and practices are not relevant to the average microbiologist's decision about whether or not to engage online. The decision to participate in face-to-face engagement, however, seems to be different. Microbiologists who view their colleagues as likely to approve of their participation in outreach (i.e., injunctive norms) are more willing to partake. Surprisingly, however, microbiologists in our study are more likely to engage in face-to-face engagement if they think their colleagues are *less* inclined to exhibit this behavior (i.e., descriptive norms). This runs counter to expectations associated with the TPB, as well as other science communication research that has unearthed evidence of the opposite relationship: that scientists are more likely to engage if they think their colleagues are doing it (32). Our finding could be the result of some microbiologists perceiving that if others are not communicating the work, they had better do the job themselves. It is hard to know without additional data; however, one interpretation seems clear: we find no evidence of a “Carl Sagan effect” among microbiologists. (The Sagan effect refers to the belief that scientists who actively engage with the public see a decline in the credibility of their own research program as a result.) This should be heartening to communication trainers seeking to help microbiologists more effectively engage with the public. To researchers of science communication, it also suggests an opportunity to explore microbiologists as unique when it comes to how norms influence their outreach.

Our results also indicate strong relationships between a scientist's age and status with her/his willingness to participate in direct and online engagement. Specifically, younger microbiologists are more willing to engage through either platform. At least one recent study finds that younger scientists are more likely to engage online (22), so it is not

necessarily surprising to see this trend among microbiologists. More notable is that younger microbiologists are more likely than their older colleagues to engage in face-to-face outreach; this finding runs counter to results showing that public engagement—especially offline engagement—has most commonly been conducted by older scientists (23, 24, 26). To take an even closer look at the relationship between age and engagement, we ran a post hoc correlation to see if age was correlated with communication training; there was not a significant relationship. Our regression results also suggest, similarly to previous studies (27, 28, 33), that more scientifically productive microbiologists are more willing to engage. A positive way to interpret these particular findings is that the future generation of microbiologists and those who are rapidly generating research are poised to engage. Conversely, it would be helpful to understand why older microbiologists seem less inclined to engage.

Our study, of course, is not without limitations. Perhaps the most noteworthy limitation is the risk of nonresponse bias, such that the respondents may have been microbiologists who held strong feelings—positive or negative—toward public engagement. This possibility is a common challenge when studying scientists as communicators (17) and explains our use of a modest incentive structure and multi-wave design. Consistent with similar research (42, 43), our respondents were also older, senior-level scientists. We believe, however, that these characteristics are offset by the sample's strengths; there is no reason to believe the responses herein would be systematically different from those of another sample drawn with a similar research design. Ideally, we would have liked to acquire data from microbiologists related to engaging through media and directly with policymakers and government officials. Unfortunately, that was not possible due to the constraints of our particular sampling pool and our desire to perform multivariate analyses. Future efforts will focus on those particular engagement modalities.

In conclusion, as noted by Shugart and Racaniello (3), microbiologists have an opportunity to contribute to public conversations about their work and its potential implications through their communication with lay audiences and the media. Understanding microbiologists' baseline engagement views and behaviors, and the factors associated with these behaviors, can help improve the microbiology community's communication footprint. Our results are positive. It seems that microbiologists are somewhat frequent communicators and that they derive great value from their outreach efforts. Our results also clarify why microbiologists may be drawn to engagement opportunities, with some of these factors—particularly age and norms—suggesting microbiologists may harbor some unique and desirable qualities relative to outreach. When considering the chorus of voices calling for the improvement and proliferation of science communication (8, 10, 49), stakeholders interested in strengthening dialogue between the microbiological sciences and the public should be encouraged by these results and consider investing further in the public communication of microbiology.

SUPPLEMENTAL MATERIALS

Appendix I: Survey questions and indices used in analyses

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