Public Understanding
of Science

A triangulated approach for understanding scientists' perceptions of public engagement with science

Journal:	*PUBLIC UNDERSTANDING OF SCIENCE*
Manuscript ID	PUS-21-0260.R1
Manuscript Type:	Research article
Keywords:	public engagement, mixed-methods, science communication, scientists

Abstract:	Scientists are expected to engage with the public, especially when society faces challenges like the COVID-19 pandemic or climate change, but what public engagement means to scientists is not clear. We use a triangulated, mixed methods approach combining survey and focus group data to gain insight into how pre-tenured and tenured scientists personally conceptualize public engagement. Our findings indicate that scientists' understanding of public engagement is similarly complex and diverse as the scholarly literature. While definitions and examples of one-way forms of engagement are the most salient for scientists, regardless of tenure status, scientists also believe public engagement with science includes two-way forms of engagement, such as citizen and community involvement in research. These findings suggest that clear definitions of public engagement are not necessarily required for its application but may be useful to guide scientists in their engagement efforts, so they align with what is expected of them.

A triangulated approach for understanding scientists' perceptions of public engagement with science

Abstract

Scientists are expected to engage with the public, especially when society faces challenges like the COVID-19 pandemic or climate change, but what public engagement means to scientists is not clear. We use a triangulated, mixed methods approach combining survey and focus group data to gain insight into how pre-tenure and tenured scientists personally conceptualize public engagement. Our findings indicate that scientists' understanding of public engagement is similarly complex and diverse as the scholarly literature. While definitions and examples of one-way forms of engagement are the most salient for scientists, regardless of tenure status, scientists also believe public engagement with science includes two-way forms of engagement, such as citizen and community involvement in research. These findings suggest that clear definitions of public engagement are not necessarily required for its application but may be useful to guide scientists in their engagement efforts, so they align with what is expected of them.

Key words: public engagement, mixed-methods, science communication, scientists

Short title: Scientists' perceptions of public engagement

Word count: 7,996

Recent arguments have been made that "the challenges posed by post-normal scientific developments … demand new and more effective infrastructure for citizen engagement" (Scheufele et al., 2021). Post-normal scientific developments are those that have high uncertainty and catastrophic potential and are often discussed in terms of the complex ethical, legal, and social implications they pose to society (Funtowicz and Ravetz, 1992). These issues range across industries and applications. For example, people may develop opinions about emerging issues like bias in artificial intelligence (AI), using technologies like solar geoengineering to mitigate the negative impacts of climate change, or uncertainty about the science behind COVID-19 vaccines. Recognizing the inextricable relationship between science and society, some in the scientific community have repeatedly advocated for the necessity of public engagement with science (National Academies of Sciences, 2017; National Science Foundation, 2020).

Engaging with the public is an inherent part of effective science communication and is foundational to the role of scientists as "public communicators" (Dudo, 2015), although what engagement means and looks like can take many forms. The current literature on public engagement lacks definitional consistency and an understanding of how scientists themselves define public engagement. Many disciplines have tackled the concept of public engagement broadly, such as in political science, education, and management (e.g., Agostino and Arnaboldi, 2016; PytlikZillig and Tomkins, 2011; Sandlin et al., 2017). Other fields have addressed public engagement with science specifically, including in environmental studies, health sciences, and communication sciences (e.g., Wang et al., 2019; Whitty, 2013; Yuan et al., 2019). This range of scholarship has led to multiple definitions for public engagement and inconsistencies in its meaning.

In this study, we compare how scholars have conceptualized public engagement with scientists' own perspectives about public engagement to understand the "mental models" (Doyle and Ford, 1999) scientists construct about public engagement. Using a triangulated mixed-methods approach, we explore scientists' perceptions of public engagement through open-ended and closed-ended survey responses combined with results from focus group discussions. By giving voice to scientists, we clarify how they understand public engagement despite its broad variation throughout scholarship. Our findings show that scientists' perceptions of public engagement are similarly as complex as the related scholarship. We explain the patterns that emerge across our data. Although traditional one-way understandings of engagement are salient to scientists, our findings also suggest that, regardless of tenure status, scientists believe public engagement with science includes citizen and community involvement in research. Addressing the emphasis that some members of the scientific community have placed on the importance of public engagement (e.g., National Academies of Sciences, 2017), we discuss how the perspectives of scientists can be leveraged to strengthen systematic efforts to improve science communication in practice.

The inconsistencies of the meaning of public engagement in scholarship

Scholars have long acknowledged the complexity of public engagement with different models. Public engagement with science was initially conceptualized as a way to increase public understanding of science, a knowledge-deficit approach to engagement that involves one-way communication strategies, like outreach, to develop public knowledge of scientific issues (Irwin and Michael, 2003; Brossard and Lewenstein, 2010; Bauer, 2009). More recent conceptualizations of public engagement include two-way communication such as valuing dialogues between scientists and the public and involving publics in scientific research (Brossard

and Lewenstein, 2010; Davies, 2008). This shift is due, in part, to the recognition of the "broader impact" that science research has on society (National Science Foundation, 2020).

Avoiding specific definitions, some scholars created broad, general definitions of public engagement that include both one-way and two-way communication (e.g., Rowe and Frewer, 2005; Besley et al., 2018). For example, defining public engagement as "any effort that might see members of the scientific community trying to engage, primarily through communication, with people outside of their area of research" (Besley et al., 2018: 560). Similarly, in an attempt to clarify varying understandings of public engagement and participation, Rowe and Frewer (2005) specify three broad forms of public engagement based on the flow of information between the public and sponsors of information: public communication, public consultation, and public participation. Within these typologies, they present 100 participation "mechanisms," or engagement activities, and discuss ways to categorize them based on key attributes. While Rowe and Frewer's thorough approach highlights the breadth of public engagement activities, such breadth makes applying their framework complex, particularly for comparisons across disciplines or institutions. An overview of different modalities was recently proposed which considers five types of engagement: public communication, public consultation, public involvement, public collaboration, and public empowerment (Scheufele et al., 2021). Effective modalities for public engagement reflect scientists' different goals of engaging with the public such as, avoiding potential controversy, educating the public, building democratic capacity through deliberation, widening representation of voices, soliciting input on value debates triggered by science, enabling responsible innovation, and shaping policy (Scheufele et al., 2021). These goals are similar to those put forth by the scientific community (i.e., National Academies of Sciences, 2017).

Public engagement is further defined by the efforts of researchers to systematically classify and measure engagement activities, which are also broadly conceptualized. Public engagement activities have been categorized in various ways such as grouped by content and purpose (Davies, 2008), based on "narratives" of outreach that consider contextual factors of activities (Johnson et al., 2013), organized by the "intensity" of individual participation in knowledge construction (Bucchi and Neresini, 2007), as well as by defining the theme, purpose, and size of the public (Schrogel and Kolleck, 2019). Scholars have also defined public engagement in more narrow terms, based on the types of engagement activities, such as interviews with journalists, taking part in public debates, giving a public lecture, and participating in a consensus conference or a science café, among others (Poliakoff and Webb, 2007; Bauer and Jensen, 2011). The variety of engagement activities differ in accessibility, required skills, and disciplinary culture. For example, researchers from the field of humanities and social sciences are more likely to interact with media than those from bench sciences (e.g., life sciences and biological sciences) (Peters, 2013). The classification of engagement activities is a common way scholars have put boundaries around the concept of public engagement in order to study it more closely in its many forms (e.g., Rowe and Frewer, 2005; Bucchi and Neresini, 2007; Schrogel and Kolleck, 2019). By doing so, however, research about the effectivness of one type of engagement cannot be generalized across types.

The lack of conceptual consistency has led to an increasingly diffuse and fragmented landscape of what public engagement means. To further complicate the situation, the terms "public communication," "public engagement," and "science communication" are often used interchangeably in the literature (Yeo and Brossard, 2017). As scientists are increasingly

expected to engage with the public, it is unclear how this broad landscape impacts how scientists personally perceive engagement and whether that might influence their willingness to engage.

The under-studied understanding of scientists' perceptions of public engagement

In addition to the fact that the concept itself is broadly defined, many public engagement studies have focused specifically on how scientists and the public engage with science, without considering the diversity of scientists' understanding of public engagement. Previous research has explored, among other things, which publics engage with science (e.g., Füchslin et al., 2019; Cámara et al., 2017), how they engage (e.g., Powell et al., 2011; Chen, 2020), public motivations for and perceptions of engagement (e.g., Kleinman et al., 2009; Jensen and Buckley, 2014), and outcomes from participation in engagement activities (e.g., Brossard et al., 2005; Rose et al., 2017). This research is useful for understanding different publics to effectively reach them but doing so depends on scientists being willing to engage with these publics in the first place.

Some of the work that focuses on scientists, rather than the public, has explored the characteristics of engaged scientists (Jensen et al., 2008; Dudo, 2013), the objectives that drive scientists' public engagement behavior (Dudo and Besley, 2016; Poliakoff and Webb, 2007), and scientists' views of the public (Besley, 2015; Besley and Nisbet, 2013). Communication scholars have examined public engagement with regards to particular "wicked" science issues and their societal applications, such as with gene editing technology (e.g., Scheufele et al., 2021; Wirz et al., 2020) and biotechnology (e.g., Braun et al., 2015).

Other studies are directed towards analyzing scientists' participation in specific types of engagement activities, such as K-12 public outreach activities (e.g., Andrews et al., 2005; Kim and Fortner, 2008), their political involvement (e.g. Kim, Corley, Scheufele, Hall, & Drive, 2017), or engagement online (e.g., Collins et al., 2016; Howell et al., 2019). Other scholars have

explored scientists as public communicators by studying their media visibility (e.g., Peters, 2013). Communication scientists have also investigated how scientists' attitudes about the public (e.g., Besley, 2015) and toward public communication (Rose et al., 2020) influence their willingness to participate in engagement activities. However, less work has specifically examined scientists' *perceptions* of public engagement. Research examining scientists' understanding of public engagement include studies regarding engagement with *specific* science issues, such as emerging biotechnologies (e.g., Braun et al., 2015), or by science communicators from *specific* fields, like environmental science and microbiology, among others (e.g., Riesch et al., 2016; Dudo et al., 2018). Previous research has also examined tactics for effective science communication that consider scientists' beliefs about engagement (Besley et al., 2019). Recently there has been a focus on scientists' perspectives of what the goals (e.g., Riesch et al., 2016) or objectives (Rose et al., 2020; Dudo and Besley, 2016) of public engagement activities are, as well as perceptions of institutional culture of support for public engagement (Bao et al., 2022).

In addition to the varied definitions and classifications discussed, public engagement also depends on a variety of contexts and variables at the individual and organizational levels (Crettaz von Roten, 2011). For example, in the U.S., tenure promotion guidelines set professional expectations of scholarly performance in teaching, research, and service at higher education institutions. These guidelines can heavily influence the ways in which scientists decide to allocate their time for their professional responsibilities and goals. This can in turn influence whether, and how much, scientists participate in public engagement. Although little research has explored if scientists at different stages of their career define public engagement differently, tenure status has been found to influence scientists' willingness to engage with the public. Previous research has shown that less autonomy (e.g., Johnson et al., 2013; Ho et al., 2020) and a

lack of tenure-reward system for public engagement (e.g., Jaeger and Thornton, 2006; Ecklund et al., 2012; Ho et al., 2020) are considered barriers for scientists willingness to participate in public engagement. These barriers can be especially salient for pre-tenure faculty who are concerned that engagement might inhibit their academic success (Martinez-Conde, 2016). For example, pre-tenure faculty may be enthusiastic about public engagement but feel inhibited to participate until tenured (Jaeger and Thornton, 2006). Despite these complexities, to our knowledge there has not been a systematic exploration into whether scientists' perceptions of public engagement are evolving as the concept has in the scholarship. Therefore, we explore the following research questions:

RQ1: How do scientists define public engagement?

RQ2: How do scientists' perceptions of public engagement deviate from how it is conceptualized throughout the scholarly literature?

RQ3: How do perceptions of public engagement differ between pre-tenure and tenured scientists?

Methods

Our analysis draws on two main sources of data to examine scientists' perceptions of public engagement: a comprehensive survey of faculty from U.S. land-grant universities and faculty focus groups at a large research university in the U.S. Land-grant universities, established by the Morrill Act of 1862, are publicly funded institutions in the U.S. that have a historical tradition of public service and practical, applied education and research (Morrill Act, 1862).

Survey data

We conducted a survey of scientists from 73 U.S. land-grant universities from May to June 2018, providing three reminders after the initial contact. The final sample included 10,706 eligible

responses from 46 U.S. land-grant universities with a completion rate of 14.1% (AAPOR, 2016). For this study, we chose a subsample of tenure-track scientists, resulting in a total sample of 6,242 respondents. For our analysis, we used a combination of responses to closed-ended and open-ended questions.

First, we analyzed responses to three batteries of closed-ended questions that asked respondents how much they agree that specific types of activities are considered public engagement, as well as their perceptions of the definition of public engagement. We report the descriptive statistics for the responses to these closed-ended questions, as well as breakdowns based on tenure status.

Second, we analyzed responses to an open-ended question that scientists saw before the close-ended questions in the survey that asked them to list the first words or terms that comes to mind when they think of "public engagement." They were provided three empty fields to fill in with their top three associations with public engagement. Among respondents, 94 percent provided at least one response, 89 percent provided at least two, and 78 percent provided three. When accounting for duplicates, the final sample included 7,925 unique word associations with the term public engagement. To develop the codebook, we used a combination of deductive and inductive approaches to extract thematic categories from the responses. We deductively created an initial codebook from the literature for baseline definitional categories of public engagement and listed examples under each category. We then selected a sample of 240 responses to test the applicability of the codebook and inductively adjusted the codebook by creating additional categories that fit the responses. The first three authors used a subset of 240 responses to test the inter-coder reliability. The Cohen's Kappa was 0.783, which reached the threshold of 0.667 for tentative conclusions (Lacy et al., 2015). The final codebook included eight main categories

related to perceptions of public engagement, including definitions, activities, goals and outcomes, motivations and barriers, sentiment, audiences, miscellaneous categories, and other non-categorized. Most of the main categories also had several sub-categories, with a total of 54 sub-categories. In our final analyses of the open-ended responses, we applied a "salience-weight" that gives greater weight to the first responses to the open-ended question to represent which word associations were most salient to respondents. We assigned 3/6, 2/6, and 1/6 as different weights for the first, second, and third responses to calculate the overall weighted index of each category.[1] The space provided for the word associations was not limited to a word count, rather it was designed to capture single words or short descriptions. Most of the responses provided are brief (57.8% one word; 21.2% two words). For the few responses containing multiple associations in one field, we coded the first association in each field to ensure that all responses are the most salient considerations participants had. When one response contained elements of different categories, we prioritized the category that provided the most context to follow the rule of mutually exclusiveness. For example, "interacting with people outside academia" falls into two categories: the "involvement" sub-category for definitions and the audience category. Since "interacting" provides the context for the answer rather than the audience of "people outside academia," this answer was coded as "involvement."

Focus group data

We conducted four focus groups of tenure-track faculty [2] (N=23) at a U.S. Midwest public land-grant university in May to June 2020. Two focus groups included tenured faculty while the other

[1] These weights represent high to low saliency. The first association has the greatest weight because it represents the association most top of mind. Weights for associations 2 and 3 decrease by proportion. These weights add up to 1, so that the sum of the weighted proportions of all categories remain 1.

[2] The sample of focus group participants include faculty in the field of arts and humanities and science, whereas the survey sample only includes science faculty.

two included pre-tenure faculty. The moderator asked participants to discuss a series of questions related to public engagement, including the first question about the definition of public engagement which asked, "what comes to mind when you think of scholars connecting or communicating with the public?" Given the many definitions and terms used to describe public engagement, we specifically excluded the term "public engagement" in our question. This enabled us to capture how participants conceptualized engagement from their own experiences. With a combined deductive and inductive approach, the focus group transcripts were coded using MAXQDA, following recommended categorization and coding practices (Rädiker and Kuckartz, 2020). Deductively, we developed principal and sub-definition types from previous literature and coded these as broad categories. We also added sub-categories based on our coding of the 2018 survey data. Inductively, we further coded additional definitions that appeared throughout the focus group discussions. When a new type of definition emerged, we recoded all transcripts to include instances in which they appeared. In our analysis, we compared the transcripts of the responses to the first question about the definition of public engagement in the four discussions to identify similarities and differences based on tenure status.

Findings

The results of this study provide valuable insight into how scientists understand public engagement. Below we detail the triangulated quantitative and qualitative findings from the closed-ended responses, open-ended responses, and focus group data.

Closed-ended responses

As described above, the closed-ended questions asked about respondents' perspectives on public engagement as including one-way or two-way forms of communication in addition to specific types of activities. Our results show that respondents perceive public engagement as including

two-way forms of communication (84.6% "agree" or "strongly agree") more than one-way forms (53.4% "agree" or "strongly agree"), as shown in Figure 1. Perceptions that public engagement includes one-way forms of communication is slightly mixed, with 22.7% of all respondents indicating that they "strongly disagree" or "disagree" and 23.9% indicating that they "neither disagree nor agree." However, few respondents (1.8%) "strongly disagree" or "disagree" that public engagement includes two-way forms of communication, and only 13.7% were neutral. These findings provide insight into a baseline understanding of how scientists perceive public engagement (R1). Additionally, we used t-tests to compare the mean response between pre-tenure and tenured scientists (RQ3, see Supplementary Table S1). Although scientists, regardless of tenure status, viewed public engagement as involving more two-way than one-way forms of communication, pre-tenure scientists have slightly higher agreement that the definition of public engagement involves two-way ($M_{pre\text{-}tenure} = 4.1$, $M_{tenured} = 4.0$, $t(6210) = 3.05$, $p = .002$) and one-way forms of communication ($M_{pre\text{-}tenure} = 3.4$, $M_{tenured} = 3.3$, $t(6207) = 2.84$, $p = .005$).

[Insert figure 1 here]

Furthermore, when provided with specific activities, respondents consistently agreed that the examples were considered public engagement (RQ1; see Figure 2). For eight out of the nine types of activities we examined, at least 80% of respondents "agreed" or "strongly agreed" that the activity was public engagement. These include "participating as an expert in public meetings and other deliberative forums" (95.7%), "giving a public lecture" (95.5%), "informal science education outside of the classroom, such as science festivals" (91.9%), "talking with journalists" (88.9%), "working with K-12 students in the classroom" (89.4%), "blogging or writing a news article/press release" (86.0%), "participating in an open house event at your institution" (83.4%), and "participating in community service activities" (80.7%). The only activity with slightly

mixed perceptions was "communicating on social media," for which 17.1 percent of respondents did not consider this to be public engagement, 22.7 percent were neutral, and about two-thirds of respondents (60.1%) agreed that it is public engagement. When we break down these findings by tenure status (RQ3), we find essentially no significant differences between the pre-tenure and tenured respondents, except their responses for communicating on social media and informal science education efforts outside of the classroom. Independent sample t-tests showed that pre-tenure respondents agreed that communicating on social media ($M_{pre\text{-}tenure} = 3.7$, $M_{tenured} = 3.5$, $t(2681) = 7.95$, $p < .001$) and informal science education efforts $M_{pre\text{-}tenure} = 4.3$, $M_{tenured} = 4.2$, $t(6208) = 2.58$, $p = .010$) are considered public engagement more than their tenured counterparts. Given that the activities presented to scientists in our close-ended questions are those commonly included in public engagement literature, the consistent agreement that these activities are considered public engagement highlights a potential alignment between how scientists perceive engagement compared to the literature (RQ2).

[Insert figure 2 here]

Open-ended responses

The patterns of frequency of the coded categories from the open-ended responses add additional context to scientists' perceptions of public engagement (RQ1). Findings of the open-ended responses (summarized in Figure 3) show that, for each of the three response fields, respondents most often associate public engagement with definitions of public engagement, followed by examples of engagement activities, sentiment, audiences, miscellaneous categories, and motivations and barriers. Respondents most frequently cited categories of definitions for the three association fields, including nearly half (49.7%) of first responses, about a third of the second responses (35.1%), and over a quarter (27.0%) for the third. Specific examples of

engagement activities were the second broad category with the most common associations with public engagement, accounting for approximately a quarter of all responses, across the three association fields (24.1%, 26.6%, and 23.2%, respectively). The last three substantive broad categories each represent about 10 percent or less of the total responses. Associations of public engagement related to sentiment, audiences, and other miscellaneous items (including non-sentiment descriptors, personal characteristics, scientific issues, and actors) accounted for an average of 10 percent (4.0%, 2.8%, and 3.2%, respectively).

[insert figure 3 here]

When considering all three associations and applying the salience-weight that provides more weight (3/6) for the first association and less weight for the third association (1/6), the findings paint a similar picture. A large minority of responses (41.0%) refer to definitions, followed by activities (24.8%), goals and outcomes (9.1%), sentiment (3.7%), miscellaneous categories (3.0%), audience (2.9%), motivations and barriers (1.8%), and other (3.0%). The distribution of responses indicates that respondents have a wide range of considerations about public engagement, providing insights into our second research question comparing these perspectives to the literature. Like the close-ended response analyses, when we break down these open-ended associations by tenure status (RQ3), we do not see meaningful differences in the main categories between the two groups.

Next, we provide more in-depth descriptions about the sub-categories of the open-ended responses (see Supplementary Table S2). When considering the sub-categories within the broader categories, the associations become more diverse. For example, although definitions are the responses most often associated with the term "public engagement," there is a wide range of definitions that are referenced. Definitions overall account for approximately four-in-ten of the

responses (41.0%). Mentions of public engagement as "outreach" remain the most common definition of public engagement. The second most frequently cited definition sub-category is the association of public engagement as "communication (one-way)" (10.2%) which includes, among others, disseminating information, explaining concepts, sharing information, and conveying, clarifying, or explaining research. Another sub-category, "involvement (two-way)" (8.4%), includes the association of public engagement with having discussions, conversations, exchanges, or dialogues with the public. Less common were associations of public engagement with "collaboration" (3.9%), "consultation" (2.1%), "service" (1.9%), "community-based" (1.7%) "extension" (1.7%), and "empowerment" (0.2%).

The associations within the sub-categories of activities showed similar patterns in which a few activities accounted for the majority of associations, but several others were also mentioned. The most common activities mentioned across all three associations were activities in the sub-categories of "presentations" (7.3%), "media" (5.2%), "policy" (3.8%), and "social media" (1.5%). Activities within the *presentation* sub-category include presenting research at a public lecture, forum, or science café. *Media* includes activities like writing op-eds, talking with journalists, or appearing on a radio show. The *policy* sub-category includes giving testimony, speaking with policy makers, or lobbying. Lastly, the *social media* category includes engagement online through outlets like Twitter and Reddit. We found some differences based on tenure status with respect to linking public engagement to specific activities. Tenured respondents were more likely to mention policy-related activities (pre-tenure 2.7%; tenured 4.1%), whereas using social media (pre-tenure 2.1%; tenured 1.3%) or participating in science festivals (pre-tenure 1.1%; tenured 0.6%) more frequently appear among responses from pre-tenure respondents.

While goals and outcomes are less than ten percent (9.6%) of the total associations, within the sub-categories defining these goals and outcomes, only two represented one percent or more of total associations: educating the public (5.7%) and addressing societal issues (1.1%). The other 14 sub-categories accounted for the remaining 2.2% of the associations under the broader goals and outcomes category. Expressions of sentiment also make up a relatively small proportion of responses, but it is interesting that there is slightly greater negative sentiment (2.2%) about public engagement than positive sentiment (1.6%). Examples of negative sentiment include descriptions of public engagement as "annoying," "counterproductive," "meaningless," "onerous," and "ineffective." In contrast, examples of positive sentiment include descriptions like "fun," "important," "meaningful," "necessary," and "useful." Scientists also associate public engagement with a variety of audiences (2.9%) such as references to engagement with "citizens," "lay people," "stakeholders," "consumers," and "industry." These perspectives captured by the open-ended responses paint a more detailed picture of the variety of ways scientists conceptualize public engagement (RQ1), highlighting a similarly diffuse and complex understanding, like the public engagement scholarship (RQ2).

Focus group discussions

The focus group responses generally reflect similar patterns to the open-ended responses. Faculty who participated in the focus groups most frequently discussed their thoughts about what connecting and communicating with the public looks like in definitional terms or by referencing specific engagement activities. There were a total of 26 coded responses from the participants who responded to the definitional question asked in the focus groups. Of these responses, 12 related to various terms, or definitions, related to public engagement (42.5%), 11 to specific activities (43.75%), two references to goals (11%), and one that did not fit into the codebook

categories and was coded as "other." Even with a limited number of responses due to the size of the focus groups, a range of definitions and activities were mentioned. Six definitional sub-categories emerged (in order of frequency): consultation (4), communication (one-way) (2), community-based (2), outreach (1), extension (1), and involvement (1). Perceptions of public engagement coded as consultation highlighted listening to and learning from the public:

> *"I think there's a few different things that comes to mind. One of them is listening. That's actually one of the big things I do during outreach is listen to people and hear what they have to say." (Pre-tenure)*

> *"It's really engagement in the sense of visiting with people, not talking at people, not talking to people. And part of visiting with people is listening, as we just heard. Listen and engage." (Tenured)*

> *"We go to them and their places and meet in community-based organizations with leaders who can really work. And so it's really a model of direct engagement with them, in their setting, trying to really be humble about what we— we're not the experts anymore, we're learning from them." (Tenured)*

The types of engagement activities that were discussed in the groups included (in order of frequency): K-12 education (4), media (4), presentation (1), science festival (1), and academic (1). The occurrence of K-12 education mentions were mostly from tenured faculty in the same discussion group. The types of K-12 activities mentioned by participants included talking to students at local high schools and middle schools and sharing their work with them, volunteering as a chaperone for field trips, and participating in reading literacy activities for children. Engagement with media was also a repeated example of public engagement, most frequently discussed by pre-tenure faculty. Two examples referenced writing op-eds while the others noted talking to reporters and conducing media interviews:

> *"You know, [name redacted] just mentioned writing op-ed columns, you know, being interviewed in various public medium, you know, in your particular area of expertise. And I think those are the— you know, they're sort of more immediate. They're not obviously the only ones, but they're more the ones you think about, right?" (Tenured)*

> *"I did a TV interview, and I did a live radio interview, because I was the person who answered the phone, and that's sort of the culture in the field." (Pre-tenure)*

The two references to goals of public engagement both related to the goal of "educating the public," but specifically in the context of their students, rather than the general public. The one perspective that did not fit into a specific category provided a nuanced perspective about public engagement beyond a one-way transfer of knowledge that considers individuals' value systems:

> *"And I have learned by my reading as well as experience, it's simply, information transfer is insufficient to communicate well. You need to touch people on the basis of values. It's not information alone that will help them to understand or certainly to appreciate, apprehend new concepts. So somehow, I think it's touching people in terms of values, moral frameworks as well. It's not just a flow of information." (Tenured)*

The findings of the focus group discussions showed similarities for tenured and pre-tenure faculty (RQ3). The range of topics – both in terms of definitions and activities – was similarly diverse for both. The only minor difference found is that there were slightly more responses from tenured faculty (15) than their pre-tenure (11) colleagues.

Discussion

The triangulated analyses of survey and focus group data effectively address our three research questions. First, we gained clarity on how scientists view public engagement generally, finding that scientists' perceptions are driven by definitions and engagement activities as examples (RQ1). However, there was wide range of views beyond definitions and activities, suggesting that scientists' views are potentially as complex and diverse as the literature (RQ2). Lastly, instead of finding differences based on tenure status, tenured and pre-tenure scientists often held similar perspectives on public engagement (RQ3). Before we discuss these relevant points, we first acknowledge that there are several limitations to our study.

This study used a triangulated approach including three forms of data from two sources that provided us with a rich dataset from which to contextualize scientists' perceptions of public engagement. However, the characteristics of the different types of data may pose challenges for comparability. For instance, the census survey was conducted with a large sample of scientists at land-grant universities (N = 6,242), making findings generalizable only to this population. The focus group discussions included a narrow group of volunteer faculty (N = 23) at one land-grant institution for context of individual experiences. Additionally, the data were collected at different time periods (summer of 2018 and 2020), which could result in differences between the responses, especially given that the COVID-19 pandemic restricted in-person engagement opportunities. However, since the focus group findings showed similar patterns to survey findings, we are confident the timing issue is not problematic.

Other limitations relate to the interpretation of the open-ended responses. First, the design of the prompt scientists received in the survey may not have allowed for expressing complex perceptions. The prompt asked scientists to "list the first words or terms" that came to their minds when they thought of public engagement and provided three fields for these answers. Although the fields had no character limit, their small size only allowed several words to be seen at once. Thus, there may have been more nuanced and complex understandings of public engagement expressed if larger, paragraph-style fields were provided. The focus group discussions provided additional nuance and complexity, which may mitigate this limitation. Secondly, a majority of the survey respondents provided single words in response to the open-ended question. One of the challenges the coders faced was trying not to over or under interpret these single words to properly code them.

The traditional knowledge-deficit approaches to engagement persist

Overall, the results from our triangulated approach showed a pattern of scientists' views towards public engagement heavily associated with definitions and activities. But some of the differences across the data indicate that scientists seem to have a narrower view of public engagement when provided with no definition or example of what public engagement is, than when prompted with examples. For example, the closed-ended responses show that scientists overwhelmingly agree that public engagement includes two-way forms of engagement, even more so than one-way forms. However, while the open-ended results indicate that scientists consider forms of two-way engagement as public engagement, the most frequent associations are more traditional one-way forms of engagement (e.g., falling into the definitional sub-categories "outreach" and "communication (one way)"). Similarly, the most common activities mentioned in the open-ended responses were presentations (7.3%) and media (5.2%), which are activities that have less direct engagement with members of the public. These results suggest that many scientists still consider public engagement from a knowledge-deficit mindset focused on information sharing and education. At the same time, we cannot know for certain that all of the scientists who understand public engagement as "outreach," for example, define outreach the same way. Therefore, it may be useful for public engagement to be clearly defined when expected in specific contexts, such as through explanations of the "broader impacts" on the public and society for NSF-funded research (National Science Foundation, 2020). It could also be advantageous for funding institutions and universities to prime scientists with an understanding of public engagement that aligns with their expectations, values, or goals. Future research could test the effectiveness of framing public engagement in certain ways to encourage participation in different engagement activities.

Beyond complex conceptualizations, two-way communication is clear

Addressing our second research question, we generally find that scientists' perceptions of public engagement are aligned with scholarship in that they are similarly diffuse and complex. While these complex perceptions include knowledge-deficit thinking, we see some reference to new conceptualizations of public engagement centered around goals and patterns that scientists understand public engagement as "two-way". This includes the kind of citizen engagement with scientific research argued necessary to meet the challenges we face in an era of ever-evolving post-normal science and technology developments (Scheufele et al., 2021). Diffuse and complex views of public engagement are well documented through our triangulated approach: closed-ended responses showed engagement as both one-way and two-way communication and across a range of activities; open-ended responses provided a wide range of perspectives from definitions to activities to goals; and examples from the focus groups provided context to scientists' experiences with these forms of engagement. The range of views makes sense since their experiences vary and so might their exposure to different definitions of public engagement in their discipline, throughout the scientific community, and in literature.

Our findings also show examples of the evolution of the field, including recent work conceptualizing engagement based on goals and the emphasis on the importance of two-way forms of engagement. For example, a recent framework of effective public engagement provides seven goals for public engagement with science issues, using the example of the gene editing technology, CRISPR (Scheufele et al., 2021). This framework includes the goal of "educating the public." This goal was mentioned in the focus group discussions, in which a faculty member describes educating the public "in such a way that is completely jargon-free, that is something that allows us to speak about a discipline and why it is important to us" (pre-tenure). While this is one personal example, of all the open-ended associations, 9.1 percent referred to goals and

outcomes. These findings that scientists' perceptions of engagement align, and even evolve, with scholarship require additional research as the culture of public engagement continues to develop.

Additionally, one clear theme we find across our triangulated approach is that scientists do perceive public engagement as including two-way engagement efforts, such as involving citizens and communities in the research process. Although two-way forms of engagement are not the *most* salient among surveyed scientists, they were prominent across all three data sources. In addition to agreement that two-way forms of communication are considered public engagement (see Figure 1), the definition sub-categories specific to two-way engagement "involvement (two-way)" and specific mentions of "two-way" accounted for an average of 8.4 percent of all open-ended responses. Of the definition sub-categories, "involvement (two-way)" was the second most frequent association (behind "communication (one-way)"). The focus group discussions also highlighted two-way forms of engagement, citing "community-based activities," and collaborating with and learning from "community-based organizations." Public engagement scholars and the broader scientific community highlight the importance of engaging directly with the public and involving them in the research process, and these findings show that some scientists do recognize that importance. These are promising findings if a goal of the broader scientific community is to shape a culture of public engagement that supports two-way engagement efforts.

Pre-tenure and tenured scientists hold similar views of public engagement

Our third research question set out to explore whether scientists' perceptions of public engagement were influenced by their tenure status, as previous research on willingness to engage has found. One difference we found was how pre-tenure scientists perceived social media as a form of public engagement more than tenured scientists, which might be explained by familiarity

of social media due to age differences. Future research could examine how social media use may influence these perspectives. There were not many other differences found between pre-tenure and tenured scientists. It may be that research on willingness to engage has less to do with how public engagement is understood and more to do with the motivations and barriers that scientists face such as a lack of resources for engagement (e.g., Ecklund et al., 2012), the perception of engagement as an opportunity cost (e.g., Martinez-Conde, 2016), or the expectations and pressures faculty experience before they are tenured (e.g., Jaeger and Thornton, 2006). Some of these motivations and barriers came up in the open-ended responses, with responses associating public engagement with being "time consuming" or "expected" as an "academic obligation" and "new requirement for tenure." Additionally, while the focus group discussions about the definition of public engagement show few differences based on tenure status, later questions in the focus groups regarding motivations, barriers, and institutional factors that influence engagement also indicate that there are potential differences based on tenure status (Calice et al., 2022). Therefore, it is not necessarily that there are not differences in perspectives on public engagement for pre-tenure and tenured scientists, but our research suggests that the broad understanding of the definition of public engagement is not where those differences exist. Future research should explore the potential of these differences and the implications they might have on encouraging scientists to engage.

Conclusion

The findings of our triangulated approach are rich with different levels of data that enabled us to explore scientists' perspectives on public engagement with a wide lens. This study provided valuable insight into our three research questions exploring how scientists perceive public engagement, how their perceptions compare to public engagement scholarship, and whether

tenure status impacts their perceptions. This research suggests that, despite the prevalence of knowledge-deficit thinking, scientists do understand public engagement in ways that science communication experts argue are necessary to bridge the relationship between science and society. And while clear definitions and expectations may be useful for funding organizations and universities aiming to evaluate engagement, external pressures to engage with the public exist beyond academe, such as from public fears surrounding science-related challenges in society like COVID-19 or climate change. It is likely that in practice, engagement will take on many forms incentivized by various goals and desired outcomes that will depend on the context of the issue and the research. Understanding how scientists conceptualize public engagement provides valuable insight into the broader concept of public engagement, which is critical for cultivating a relationship between scientists working through these evolving science-related challenges and the publics affected by them.

References

AAPOR (2016) *Standard definitions: Final dispositions of case codes and outcome rates for surveys.* Lenexa, KS: American Association for Public Opinion Research.

Agostino D and Arnaboldi M (2016) A measurement framework for assessing the contribution of social media to public engagement: An empirical analysis on Facebook. *Public Management Review* 18(9): 1289-1307.

Andrews E, Weaver A, Hanley D, et al. (2005) Scientists and public outreach: Participation, motivations, and impediments. *Journal of Geoscience Education* 53(3): 281-293.

Bao L, Calice MN, Brossard D, et al. (2022) How institutional factors at US land-grant universities impact scientists' public scholarship. *Public Understanding of Science*. DOI: 10.1177/09636625221094413.

Bauer MW (2009) The evolution of public understanding of science—discourse and comparative evidence. *Science, Technology and Society* 14(2): 221-240.

Bauer MW and Jensen P (2011) The mobilization of scientists for public engagement. *Public Understanding of Science* 20(1): 3-11.

Besley JC (2015) What do scientists think about the public and does it matter to their online engagement? *Science and Public Policy* 42(2): 201-214.

Besley JC, Dudo A, Yuan S, et al. (2018) Understanding scientists' willingness to engage. *Science Communication* 40(5): 559-590.

Besley JC and Nisbet MC (2013) How scientists view the public, the media and the political process. *Public Understanding of Science*. DOI: 10.1177/0963662511418743.

Besley JC, O'Hara K and Dudo A (2019) Strategic science communication as planned behavior: Understanding scientists' willingness to choose specific tactics. *PLOS ONE* 14(10): e0224039.

Braun M, Starkbaum J and Dabrock P (2015) Safe and sound? Scientists' understandings of public engagement in emerging biotechnologies. *PLOS ONE* 10(12): e0145033.

Brossard D and Lewenstein BV (2010) A critical appraisal of models of public understanding of science: Using practice to inform theory. In: Kahlor L and Stout P (eds) *Communicating Science: New Agendas in Communication*. New York: Routledge, pp.11-39.

Brossard D, Lewenstein BV and Bonney R (2005) Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education* 27(9): 1099–1121.

Bucchi M and Neresini F (2007) Science and Public Participation. In: Hackett EJ, Amsterdamska O, Lynch M, et al. (eds) *Handbook of Science and Technology Studies, Third Edition*. Cambridge: M I T Press, pp.449-472.

Calice MN, Beets B, Bao L, et al. (2022) Public engagement: Scientists' lived experiences and perspectives underscore barriers and a changing culture in academia. *PLOS ONE*.

Cámara M, Muñoz van den Eynde A and López Cerezo JA (2017) Attitudes towards science among Spanish citizens: The case of critical engagers. *Public Understanding of Science* 27(6): 690-707.

Chen K (2020) How deliberative designs empower citizens' voices: A case study on Ghana's deliberative poll on agriculture and the environment. *Public Understanding of Science* 30(2): 179-195.

Collins K, Shiffman D and Rock J (2016) How are scientists using social media in the workplace? *PLOS ONE* 11(10): e0162680.

Davies SR (2008) Constructing communication: Talking to scientists about talking to the public. *Science Communication* 29(4): 413-434.

Doyle JK and Ford DN (1999) Mental models concepts revisited: some clarifications and a reply to Lane. *System Dynamics Review* 15(4): 411-415.

Dudo A (2013) Toward a model of scientists' public communication activity. *Science Communication* 35(4): 476-501.

Dudo A (2015) Scientists, the media, and the public communication of science. *Sociology Compass* 9(9): 761-775.

Dudo A and Besley JC (2016) Scientists' prioritization of communication objectives for public engagement. *PLOS ONE* 11(2): e0148867.

Dudo A, Besley JC, Kahlor LA, et al. (2018) Microbiologists' public engagement views and behaviors. *Journal of Microbiology & Biology Education* 19(1): 1-8.

Ecklund EH, James SA and Lincoln AE (2012) How academic biologists and physicists view science outreach. *PLOS ONE* 7(5): e36240.

Füchslin T, Schäfer MS and Metag J (2019) Who wants to be a citizen scientist? Identifying the potential of citizen science and target segments in Switzerland. *Public Understanding of Science* 28(6): 652-668.

Funtowicz SO and Ravetz JR (1992) Three types of risk assessment and the emergence of post-normal science. In: Krimsky S and Golding D (eds) *Social Theories of Risk*. Praeger, pp.251-274.

Ho SS, Looi J and Goh TJ (2020) Scientists as public communicators: Individual- and institutional-level motivations and barriers for public communication in Singapore. *Asian Journal of Communication* 30(2): 155-178.

Howell EL, Nepper J, Brossard D, et al. (2019) Engagement present and future: Graduate student and faculty perceptions of social media and the role of the public in science engagement. *PLOS ONE* 14(5): e0216274.

Irwin A and Michael M (2003) *Science, social theory, and public knowledge.* Philadelphia, PA: Open University Press.

Jaeger AJ and Thornton CH (2006) Neither honor nor compensation: Faculty and public service. *Educational Policy* 20(2): 345-366.

Jensen E and Buckley N (2014) Why people attend science festivals: Interests, motivations and self-reported benefits of public engagement with research. *Public Understanding of Science* 23(5): 557-573.

Jensen P, Rouquier J-B, Kreimer P, et al. (2008) Scientists who engage with society perform better academically. *Science and Public Policy* 35(7): 527-541.

Johnson DR, Ecklund EH and Lincoln AE (2013) Narratives of science outreach in elite contexts of academic science. *Science Communication* 36(1): 81-105.

Kim C and Fortner RW (2008) Great lakes scientists' perspectives on K-12 education collaboration. *Journal of Great Lakes Research* 34(1): 98-108.

Kleinman DL, Delborne JA and Anderson AA (2009) Engaging citizens: The high cost of citizen participation in high technology. *Public Understanding of Science* 20(2): 221-240.

Lacy S, Watson BR, Riffe D, et al. (2015) Issues and best practices in content analysis. *Journalism & Mass Communication Quarterly* 92(4): 791-811.

Martinez-Conde S (2016) Has contemporary academia outgrown the Carl Sagan effect? *The Journal of Neuroscience* 36(7): 2077-2082.

Morrill Act (1862) Morrill Act of 1862.

National Academies of Sciences, Engineering, and Medicine (2017) *Communicating science effectively: A research agenda.* Washington, DC: The National Academies Press.

National Science Foundation (2020) *NSF proposal processing and review*. Available at: https://www.nsf.gov/pubs/policydocs/pappg20_1/pappg_3.jsp.

Peters HP (2013) Gap between science and media revisited: Scientists as public communicators. *Proceedings of the National Academy of Sciences of the United States of America* 110(Supplement 3): 14102-14109.

Poliakoff E and Webb TL (2007) What factors predict scientists' intentions to participate in public engagement of science activities? *Science Communication* 29(2): 242-263.

Powell M, Colin M, Lee Kleinman D, et al. (2011) Imagining ordinary citizens? Conceptualized and actual participants for deliberations on emerging technologies. *Science as Culture* 20(1): 37-70.

PytlikZillig LM and Tomkins AJ (2011) Public engagement for informing science and technology policy: What do we know, what do we need to know, and how will we get there? *Review of Policy Research* 28(2): 197-217.

Rädiker S and Kuckartz U (2020) *Focused analysis of qualitative interviews with MAXQDA*. Available at: https://www.maxqda-press.com/catalog/books/focused-analysis-of-qualitative-interviews-with-maxqda.

Riesch H, Potter C and Davies L (2016) What is public engagement, and what is it for? A study of scientists' and science communicators' views. *Bulletin of Science, Technology & Society* 36(3): 179-189.

Rose KM, Korzekwa K, Brossard D, et al. (2017) Engaging the public at a science festival: Findings from a panel on human gene editing. *Science Communication* 39(2): 250-277.

Rose KM, Markowitz EM and Brossard D (2020) Scientists' incentives and attitudes toward public communication. *Proceedings of the National Academy of Sciences of the United States of America* 117(3): 1274-1276.

Rowe G and Frewer LJ (2005) A typology of public engagement mechanisms. *Science Technology & Human Values* 30(2): 251-290.

Sandlin JA, Burdick J and Rich E (2017) Problematizing public engagement within public pedagogy research and practice. *Discourse: Studies in the Cultural Politics of Education* 38(6): 823-835.

Scheufele DA, Krause NM, Freiling I, et al. (2021) What we know about effective public engagement on CRISPR and beyond. *Proceedings of the National Academy of Sciences* 118(22): e2004835117.

Schrogel P and Kolleck A (2019) The many faces of participation in science: Literature review and proposal for a three-dimensional framework. *Science and Technology Studies* 32(2): 77-99.

Wang S, Wang J, Lin S, et al. (2019) Public perceptions and acceptance of nuclear energy in China: The role of public knowledge, perceived benefit, perceived risk and public engagement. *Energy Policy* 126: 352-360.

Whitty JA (2013) An international survey of the public engagement practices of health technology assessment organizations. *Value in Health* 16(1): 155-163.

Wirz CD, Scheufele DA and Brossard D (2020) Societal debates about emerging genetic technologies: Toward a science of public engagement. *Environmental Communication* 14(7): 859-864.

Yeo SK and Brossard D (2017) The (changing) nature of scientist–media interactions: A cross-national analysis. In: Jamieson KH, Kahan D and Scheufele DA (eds) *The Oxford Handbook of the Science of Science Communication*. New York: Oxford University Press, pp.261-272.

Yuan S, Dudo A and Besley JC (2019) Scientific societies' support for public engagement: an interview study. *International Journal of Science Education Part B-Communication and Public Engagement* 9(2): 140-153.

Figures

Figure 1

Breakdowns by tenure status of responses to closed-ended questions comparing scientists' perceptions of public engagement as including one-way or two-way forms of communication. Faculty, regardless of tenure status, view public engagement as involving more two-way than one-way forms of communication

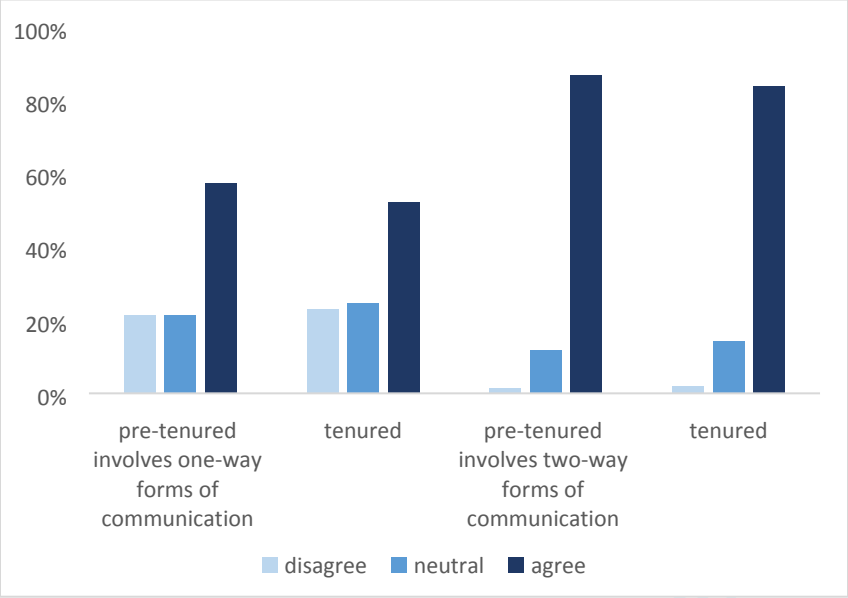


Figure 2

Scientists' responses to closed-ended survey question asking, "When I think of public engagement activities, I include the following…" Faculty show overwhelming agreement associating specific activities with public engagement.

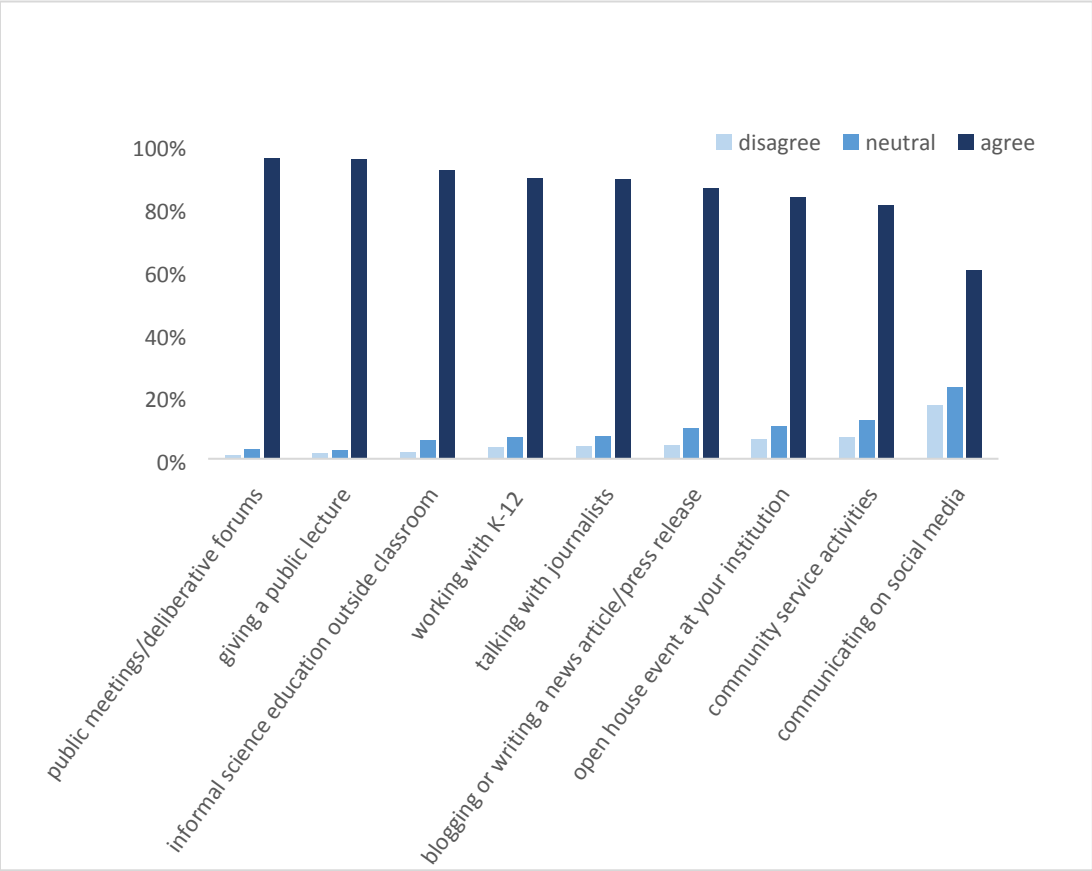
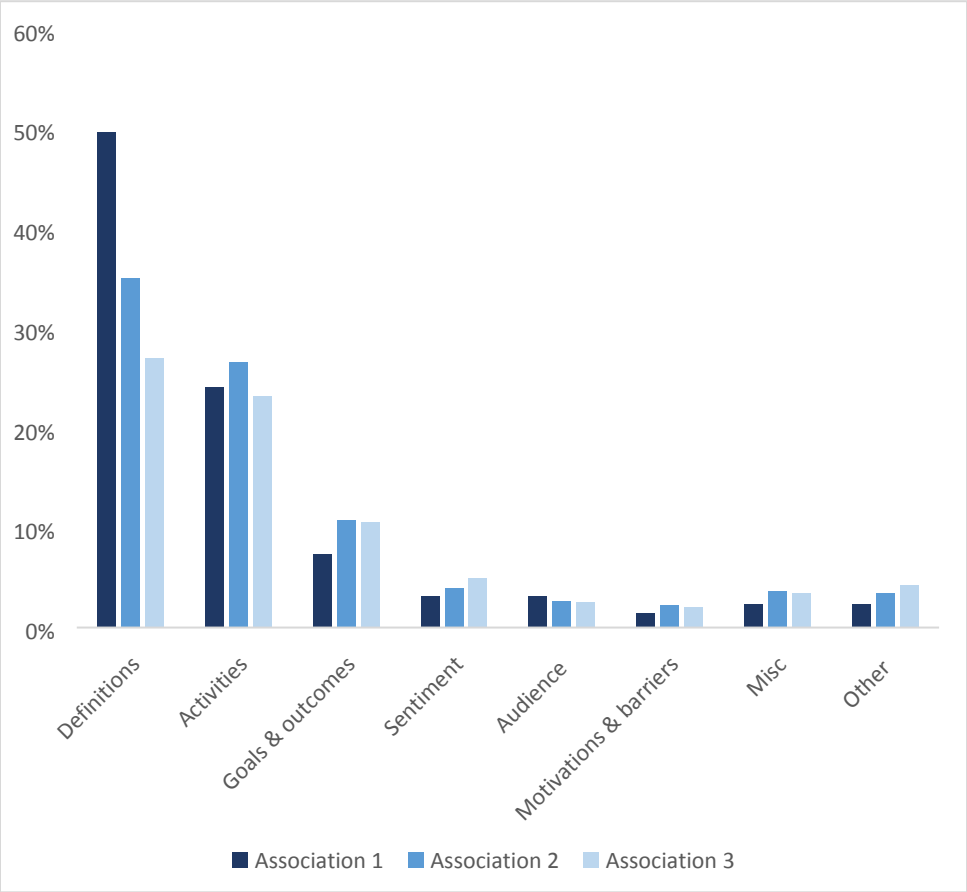


Figure 3

Scientists' responses to open-ended survey question with spaces for three word or phrase associations asking, "When I think of public engagement activities, I include the following…" Faculty consistently associate public engagement with definitions of public engagement and specific examples of engagement activities.



A triangulated approach for understanding scientists' perceptions of public engagement with science

Supplementary

Table S1
Mean comparisons (t-tests) of pre-tenure and tenured faculty's understanding of public engagement formats and activities (close-ended survey questions).

		Pre-tenure			Tenured			T-tests	
		Mean	SD	N	Mean	SD	N	t	Sig. (2-tailed)
I think public engagement ...	involves two-way forms of communication, such as a panel or discussion.	4.10	0.64	1475	4.04	0.67	4737	3.05	0.002
	involves one-way forms of communication, such as a lecture or science demonstration.	3.39	1.00	1474	3.31	0.98	4735	2.84	0.005
When I think of public engagement activities, I include …	any communication efforts, including blogging or writing a news article/press release.	4.06	0.72	1475	4.05	0.74	4736	0.57	0.567
	giving a public lecture.	4.30	0.63	1475	4.33	0.63	4737	-1.38	0.167
	talking with journalists.	4.13	0.74	1475	4.16	0.74	4737	-1.66	0.098
	communicating on social media, such as Tweeting about your research.	3.69	0.94	1475	3.46	1.03	4734	7.95	<.001
	informal science education efforts outside of the classroom, such as science festivals.	4.25	0.63	1475	4.20	0.67	4735	2.58	0.010
	working with K-12 youth in classroom	4.20	0.72	1475	4.19	0.74	4738	0.43	0.666
	participating as an expert in public meetings and other deliberative forums.	4.32	0.60	1475	4.33	0.61	4737	-0.46	0.649
	participating in community service activities.	3.98	0.84	1475	3.99	0.83	4737	-0.29	0.770
	participating in an open house event at your institution.	3.97	0.80	1475	4.00	0.78	4736	-1.44	0.149

Notes: All items were measured on a 5-point scale (1=strongly disagree, 5=strongly agree).

Table S2
Breakdowns of categories and sub-categories of the open-ended question: *People have different views on what public engagement is or means. In the space below, list the first words or terms that come to mind when you hear or see the words "public engagement."* Percentages provided for each space (field) as well as the weighed total for each category and sub-category.

Categories & sub-categories	Field 1	Field 2	Field 3	Weighted total %
Definitions	**49.7%**	**35.1%**	**27.0%**	37.3%
Communication (one-way)	12.0%	9.2%	6.9%	9.4%
Consultation	1.6%	2.9%	2.2%	2.2%
Involvement (two-way)	10.1%	7.3%	5.6%	7.7%
Collaboration	4.1%	3.9%	3.2%	3.8%
Empowerment	0.1%	0.2%	0.4%	0.2%
Outreach	12.9%	3.9%	2.2%	6.3%
Service	2.3%	1.8%	1.2%	1.8%
Engagement	0.3%	0.7%	0.5%	0.5%
One-way		0.0%	0.0%	0.0%
Two-way	0.6%	0.3%	0.4%	0.4%
Community-based	2.3%	1.2%	0.9%	1.5%
Extension	2.2%	1.4%	0.9%	1.5%
Other definition	1.3%	2.2%	2.4%	2.0%
Activities	**24.1%**	**26.6%**	**23.2%**	24.6%
Policy	3.9%	3.8%	3.3%	3.7%
Media	4.2%	6.6%	5.0%	5.3%
Social media	1.2%	1.7%	1.8%	1.6%
Science education - K12	0.6%	1.0%	0.8%	0.8%
Citizen science	0.5%	0.7%	0.7%	0.6%
Presentations	8.8%	6.5%	4.2%	6.5%
Science festivals	0.5%	0.8%	1.1%	0.8%
Activism	0.9%	0.7%	0.7%	0.8%
Advocacy	0.7%	0.7%	0.8%	0.7%
Volunteer	0.3%	0.3%	0.4%	0.3%
Academic	0.9%	1.7%	1.4%	1.3%
Training	0.1%	0.1%	0.1%	0.1%
Other activities	1.7%	2.0%	2.9%	2.2%
Goals & Outcomes	**7.4%**	**10.8%**	**10.6%**	9.6%
Avoid potential controversy	0.4%	0.3%	0.5%	0.4%
Educate the public	4.7%	7.2%	5.9%	5.9%
Build democratic capacity through deliberation	0.4%	0.3%	0.2%	0.3%
Widen representation of voices	0.3%	0.3%	0.7%	0.4%

Solicit input on value debates triggered by science				
Enable responsible innovation				
Shape policy	0.0%	0.0%	0.1%	0.0%
Broader impact	0.2%	0.2%	0.2%	0.2%
Address societal issues	0.8%	1.3%	1.4%	1.2%
Build trust	0.1%	0.2%	0.2%	0.2%
Get people excited about science	0.1%	0.1%	0.3%	0.2%
Mentorship			0.0%	0.0%
Student recruitment		0.0%	0.1%	0.0%
Persuade	0.1%	0.2%	0.2%	0.2%
Product to market		0.0%	0.0%	0.0%
Other goals	0.2%	0.6%	0.6%	0.5%
Motivations & Barriers	**1.4%**	**2.2%**	**2.0%**	1.9%
Institutional incentives	0.1%	0.2%	0.2%	0.2%
Personal objectives	1.2%	1.4%	1.2%	1.2%
Institutional barriers	0.0%	0.1%	0.1%	0.1%
Personal barriers	0.0%	0.2%	0.1%	0.1%
Other motivations/ barriers	0.1%	0.4%	0.3%	0.3%
Sentiment	**3.2%**	**3.9%**	**5.0%**	**4.0%**
Negative	1.8%	2.4%	2.8%	2.3%
Positive	1.4%	1.6%	2.1%	1.7%
Audiences	**3.1%**	**2.7%**	**2.5%**	**2.8%**
Audiences	3.1%	2.7%	2.5%	2.8%
Miscellaneous	**2.4%**	**3.6%**	**3.5%**	**3.2%**
Non-sentiment descriptors	1.5%	2.4%	2.6%	2.2%
Personal characteristics	0.1%	0.2%	0.2%	0.2%
Scientific issues	0.4%	0.6%	0.5%	0.5%
Actors	0.4%	0.4%	0.2%	0.3%
Other, Not categorized	2.4%	3.5%	4.3%	3.4%
Irrelevant	0.5%	0.2%	0.3%	0.3%
Blank	5.7%	11.5%	21.6%	12.9%