# How to get your feet wet in public engagement: Perspectives from freshwater scientists

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**Abstract:** Freshwater scientists, like scientists in other fields, are increasingly participating in public engagement with science (PES) activities. Published surveys and analyses of keywords in abstracts associated with the Society for Freshwater Science journal and annual meetings indicate that many scientists are interested in pursuing PES opportunities but find it challenging to get started because of limited time, training, collaborators, or resources. Given these issues, the objective of this paper is to synthesize strategies to break down barriers to effective and successful PES involvement by scientists. We present 3 examples of PES activities to highlight various pathways to successful PES. Additionally, we examine the practicalities of scientist engagement with the public and opportunities for creating those interactions. Drawing upon our experiences and existing literature, we recommend that scientists who are beginning with PES efforts: 1) start small with manageable projects; 2) leverage skills and resources that they already have as scientists, communicators, and community members; 3) nurture their own network of scientists, educators, and the broader community; and 4) design their PES activities for the target audience. We encourage scientists to be experimental with their PES activities, to observe the outcomes, and to learn from and share their experiences.
**Key words:** public engagement with science, science communication, informal science education, outreach, social media, exhibit design

The importance of public engagement with science (PES) is increasingly recognized by both funding agencies and individual scientists (NSF 2015, AAAS 2016). There are diverse reasons for participating in PES, ranging from a researcher's personal aspiration to communicate broader aspects of their own research (Olson 2015) and interact with the public as a civic scientist (sensu Poliakoff and Webb 2007) to the practical need to fulfill requirements from funding agencies. Regardless of the motivation, any PES activity must be planned and executed as carefully as any scientific experiment (Varner 2014).

To engage non-expert audiences, scientists employ a wide range of PES activities (Table 1), the choice of which depends on the available resources, personal skills and preferences of the scientist, and the needs of the target audience. Resources are generally characterized in terms of time, materials (e.g., supplies or specimens), and the amount of funding available. Just as important as resource availability, the

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Table 1. Examples of public engagement with science activities that may be used by scientists, ranked in terms of time commitment by the scientist, relative financial costs, and audience reach as size and duration of activity. Time commitment: low = 0 to 25 h, medium = 26 to 50 h, high = >50 h; financial costs: low = no cost (except time), medium = <$1000 (USD), high = >$1000 (USD); audience size: small = <100 participants, large = >100 participants; duration of activities: occasional = 1-time event, short = activities occur over several months, long = activities repeated over years.

| | | | Audience reach | |
|---|---|---|---|---|
| Activity | Time commitment | Financial cost | Size | Duration |
| Public lectures | medium | low | small | occasional |
| Film screenings | low | low | small | occasional |
| Film production | high | high | large | long |
| University class service-learning projects | medium | medium | small | short |
| Connections with non-profit organizations | medium | low | large | long |
| Podcasts | high | medium | large | occasional |
| Social media posts | medium | low | large | occasional |
| Museum exhibits[a] | high | high | large | short |
| Science cafés[b] | medium | medium | small | occasional |
| Citizen science activities[c] | medium | low | large | short |
| Conversations with policy makers | medium | low | small | short |
| School presentations | medium | medium | small | occasional |
| Science fair judging | low | low | small | occasional |

[a] Exhibits may be presented in diverse museum settings (natural history, art, history, anthropology, etc.).
[b] Science cafés provide public forums for scientists to engage in conversation in a casual setting (e.g., coffee shops, libraries, breweries).
[c] These activities create research collaborations between scientists and community members (e.g., stream monitoring, bird count program, bioblitzes).

experience and confidence of the scientist can determine the shape and scope of the project (Dudo and Besley 2016). Furthermore, different audiences have different expectations for scientists in terms of the relative amount of interaction, so scientists must consider the motivations, values, and beliefs of the target audience when developing PES activities (Bell et al. 2009, Simon 2016, Jones and Crow 2017).

There is a range of formats and timeframes for PES that may appeal to different scientists and their audiences. Many PES activities take place within non-school settings—sometimes referred to as informal environments or free-choice learning environments (Bell et al. 2009, Falk and Dierking 2010)—that encompass everyday experiences in the natural world (e.g., hiking or fishing), in designed environments (e.g., museums or botanic gardens), and in programs and activities in non-school settings (e.g., watching a science documentary or following a Twitter campaign) (Bell et al. 2009, Falk and Dierking 2010). Within these different settings, some audiences seek engagement and other audiences seek information (Hara et al. 2019). For example, working with youth in a summer program may require a high level of interaction and hands-on activities, whereas adult audiences may be more satisfied with lecture-like interactions. New technologies, such as social media platforms like Twitter, offer scientists an increasing number of options and formats for engaging directly with non-expert audiences (Côté and Darling 2018), and there is a developing body of knowledge about designing effective social media campaigns (e.g., Yeo 2015).

Freshwater scientists are interested in various types of public engagement, and some are already participating in PES in their own communities. A recent survey of freshwater scientists found that virtually all respondents ($n = 43$) considered PES as "important" or "very important" to their professional careers and identified high levels of experience (100%) and interest (97%) in doing PES activities (Hopfensperger et al. 2021). To further examine PES activity by members of the Society for Freshwater Science (SFS), we reviewed abstracts in the journal Freshwater Science (formerly the Journal of North American Benthological Society [JNABS]) from 1997 to 2019 and abstracts from oral presentations at the SFS Annual Meeting (available online for 1997–2012 and 2015–2019 at https://sfsannualmeeting.org/SearchAll.cfm) for key words (public engagement, science communication, education, outreach) related to PES. Throughout this period, the key words appeared infrequently in papers published in JNABS or Freshwater Science, except in 2014 when a *BRIDGES* cluster, "The Role of Conservation Partnerships in Advancing Freshwater Science and Management", included several papers that discussed the value of outreach (Fig. 1). Abstracts for talks at SFS meetings did not feature any of these key words until the last decade (Fig. 1), although trends suggest that SFS

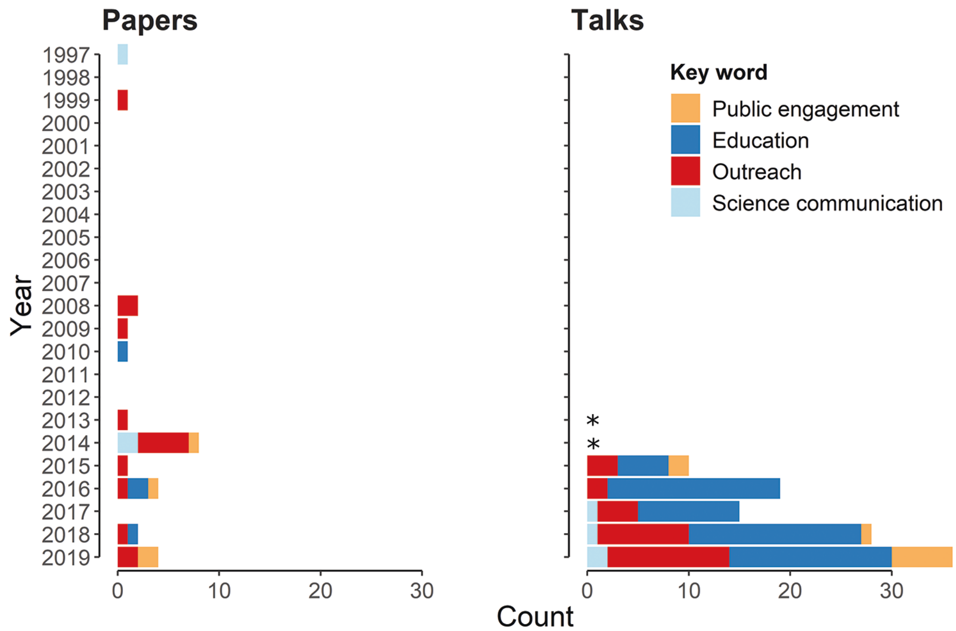


Figure 1. Bar graph showing the number of times each of 4 key words (public engagement, education, outreach, or science communication) were used in the title or abstract of published papers in Freshwater Science (formerly the Journal of the North American Benthological Society) and oral presentations (talks) at the annual Society for Freshwater Science meetings from 1997 to 2019. Some abstracts may contain more than one of these key words. Asterisks (*) indicate years for which talk abstracts were not available (2013 and 2014).

presenters are now sharing their PES activities with their peer network.

There is increasing interest and involvement in PES, but there are still barriers to participation. In 10 published surveys that asked scientists about PES involvement, most respondents (>74%) had recently participated in PES activities (with the exception of 1 study; Ndlovu et al. 2016), but respondents still identified several barriers to their efforts. Barriers included finding time and resources within academic and professional settings, having appropriate skills, finding an audience, and having the impression that PES efforts are not recognized or rewarded by institutional or peer networks (Table 2). These challenges are exacerbated by scientists' unfamiliarity with PES approaches and strategies and the lack of available PES training (TNS-BMRB and PSI 2015).

The results of these published surveys and SFS abstract analyses highlight scientists' interest in PES but also underline the concerns about barriers related to time commitments, resources, and collaborations that are needed to make PES activities effective. Given these practical and conceptual concerns, the objective of this paper is to synthesize key strategies for overcoming many of the PES participation barriers identified by scientists. We took a 2-step approach to address this objective. First, we present 3 PES examples from our own experiences as scientists and museum professionals. These examples describe many of the practicalities associated with orchestrating PES activities in general. Then, we draw upon our 3 examples and the PES literature to identify strategies for scientists seeking to "get their feet wet" in PES activities. We acknowledge that not all scientists will share our experiences and motivations, and we encourage individuals to use these guidelines to explore different points of entry into their own PES activities.

## PES EXAMPLES FROM FRESHWATER SCIENTISTS

Here we present 3 examples of PES activities: an outdoor exhibit, an indoor museum exhibit, and a social media campaign (Fig. 2A–C). These examples vary in cost, time commitment, skills/tools employed, and audience size (Table 3). The 2 exhibit projects were part of *Energize New Mexico*, a National Science Foundation-funded initiative of New Mexico Established Program to Stimulate Competitive Research (NM EPSCoR), whereas the social media campaign is an ongoing, voluntary project of an individual scientist. We discuss project motivation, highlight resources, and discuss challenges and outcomes for each example.

### Algae education station

An algae education station was constructed in 2018 at Tingley Beach, part of the City of Albuquerque BioPark complex in Albuquerque, New Mexico, to introduce visitors to the wonders of algae and pond ecosystems as part of a broader management goal to decrease algal blooms (Fig. 2A). More than 200,000 people visit Tingley Beach

Table 2. Summary of surveys of scientists about their participation in public engagement with science (PES) activities. Motivation is reported in 2 parts: as percentages (or similar assessment) of scientists who had recently participated in a PES activity and of scientists who considered PES to be important. Barriers are reported as time (their availability to participate), skills/training (not having the correct skillset or access to appropriate training), audience (finding the right group to engage), lack of institutional or peer support (not receiving rewards, support, or accolades from their institutions or collegial network), and resources and funding (having access to resources and knowledge of funding sources). $n$ = number of survey responses, ✓ = identified as a barrier, ✗ = identified as not a barrier, NA = not reported.

| | | | | Motivation | | Barriers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey | Scope | Timeframe | $n$ | Participation | Importance | Time | Skills/ training | Audience | Institutional or peer support | Resources and funding | Reference |
| Media skills training | Australia | 1992–1993 | 178 | NA | NA | ✓ | ✓ | NA | ✓ | NA | Gascoigne and Metcalfe 1997 |
| Danish survey | Denmark | 2004–2005 | 1038 | ranked high | ranked high | NA | NA | NA | NA | NA | Nielsen et al. 2007 |
| The Royal Society | Britain | 2006 | 1500 | 74% | 49% | ✓ | ✓ | NA | ✓ | ✓ | The Royal Society 2006 |
| BBSRC survey - PhD students | UK | 2014 | 104 | 74% | 29% | ✓ | ✓ | ✓ | ✗ | ✓ | Jones 2014 |
| BBSRC survey - researchers | UK | 2014 | 163 | 83% | 53% | ✓ | ✓ | ✓ | ✗ | ✓ | Jones 2014 |
| NUST survey | Zimbabwe | 2014 | 198 | 28% | NA | ✓ | ✓ | ✓ | ✓ | ✓ | Ndlovu et al. 2016 |
| Nobel Laureate meetings | International | 2014–2018 | 988 | 100% | 68% | NA | ✓ | NA | NA | NA | Könneker et al. 2019 |
| PER survey | Britain | 2015 | 2450 | 78% | 58% | ✓ | ✓ | ✓ | ✓ | ✓ | TNS-BMRB and PSI 2015 |
| Land-grant universities | USA | 2018 | 6242 | 98% | 53% | NA | ✗ | ✗ | ✓ | NA | Rose et al. 2020 |
| SFS members | International | 2019 | 43 | 100% | 97% | ✓ | ✓ | ✓ | ✓ | ✓ | Hopfensperger et al. 2021 |

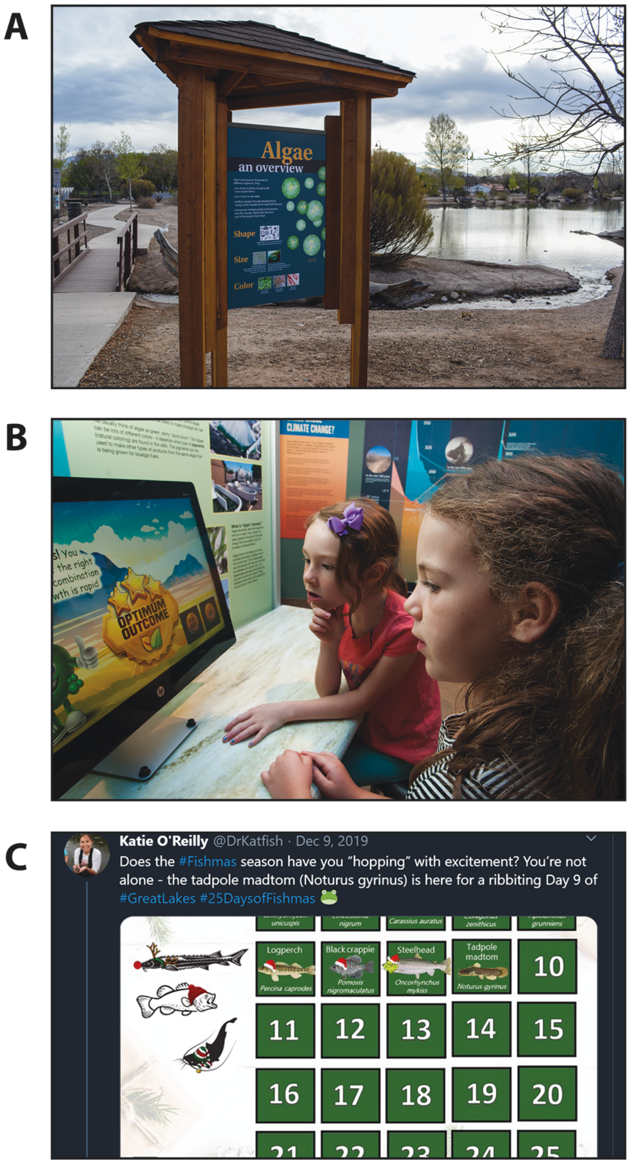


Figure 2. Algae information station designed to inform the public about algae in the nearby fishing ponds at Tingley Beach, Albuquerque BioPark, Albuquerque, New Mexico, USA (photo: Emma Brinley Buckley) (A). Children of 2 of the authors learn how to grow virtual algae by playing a computer game incorporated into the *Get Going with Green Goop* exhibit on algal biofuels at the New Mexico Museum of Natural History and Science, Albuquerque, New Mexico (photo: Mark Kotanchik) (B). An example of an introductory tweet in a daily #25DaysofFishmas thread that shows the Fishmas calendar (C).

every year for recreational activities like fishing, pedal boating, and riding the narrow-gauge railroad to the nearby zoo or botanic garden in the BioPark complex. Visitors encounter the algae education station near the park's 4 large fishing ponds (Fig. 2A) where algal blooms occur in summer. The creation of this education station was motivated by conversations among visitors, BioPark staff, and university faculty about the public perceptions of the algal blooms (Table 3).

Creating an outdoor exhibit is challenging—the display must be robust enough to withstand exposure to the elements and attractive enough to appeal to a broad audience. The 3-sided algae education station with simple graphics was designed to engage the public in topics like algal diversity, pond food webs, water resource management, and applied uses for algae. This diversity of topics was intended to spark interest in subjects that visitors may already be familiar with from personal experiences. The station can be seen by both incidental visitors (e.g., anglers, walkers) and school groups, and the strategic backdrop of live algae in the ponds also helps make the connection between the information on the panels and the actual organisms.

There was no formal visitor evaluation after the station was installed because of budget constraints but there were informal ways to evaluate the station outcomes. Ideally, an evaluation could be used to document and understand the change in visitor perceptions of algal blooms at Tingley Beach. A simple measure of impact is the number of people who have had the opportunity to interact with the station (Table 3). BioPark staff report that the education station has been visited by many locals who are not necessarily looking for an educational experience but who have incidentally learned about algae as they walk by the exhibit. Furthermore, a public lecture about algae that connected to a small number of people was held during the grand opening. These complementary PES components ensure that a diverse audience can access the station over time while a self-selecting audience can dive deeper with the lecture.

### *Get Going with Green Goop* exhibit

*Get Going with Green Goop* is an indoor exhibit about algal biofuels at the New Mexico Museum of Natural History of Science as part of the larger NM EPSCoR project. The exhibit is a 2-sided stand with large, colorful information panels incorporated into a larger exhibit about climate change (Fig. 2B). Visitors are encouraged to interact with the exhibit by touching models of algal cells, watching short videos of scientists discussing their research projects, and playing an interactive computer game to manipulate conditions to grow algae for biofuels (http://algae-biofuel.nmnaturalhistory.org/#). Additionally, museum staff developed education programs, hosted public lectures by scientists, and trained high school interns to discuss the content of the exhibit and interact with visitors.

This exhibit is a large and complex project that required significant contributions from a network of collaborators (Table 3). NM EPSCoR staff created links between the contributors and administered funds, researchers from 4 universities across the state were interviewed and provided content, and museum staff created the exhibit (audience

Table 3. Summary of 3 examples of public engagement with science activities: algae information station, the *Get Going with Green Goop* museum exhibit, and #25DaysofFishmas Twitter campaign including costs, materials, time commitment, collaborators, and audience reach. Two of the examples received funding from Energize New Mexico, a National Science Foundation-funded initiative of New Mexico Established Program to Stimulate Competitive Research (NM EPSCoR). The mission of Energize New Mexico was to support state-wide science research capacity through building and strengthening scientific enterprise and developing a diverse and well-qualified scientific workforce. NA = not applicable. NMMNHS = New Mexico Museum of Natural History and Science.

| Case study | Algae Information Station | *Get Going with Green Goop* | #25DaysofFishmas |
|---|---|---|---|
| Description | Outdoor kiosk highlighting aspects of algae at a city-owned park | Small museum exhibit about algal biofuel research | Social media campaign in which fish facts are shared daily during the month of December |
| Purpose of project | Inform public about algae including the management of summer algal blooms in the park's constructed fishing ponds | Introduce local scientists and their algal biofuel projects to public audiences | Increase awareness of aquatic biodiversity in the Laurentian Great Lakes |
| Funding source | NM EPSCoR funding for local partnerships; funds used for materials | NM EPSCoR funding used to purchase supplies and provide stipends for students involved in exhibit development | NA – Volunteer effort |
| Direct cost (USD) | $1500 | $30,000 | $0 |
| In-kind cost (USD)[a] | $2640 | $23,000 | $1040 |
| Total cost (USD) | $4140 | $53,000 | $1040 |
| Tools used | Photo editing and presentation software to create graphics, compound microscope with digital camera for imaging, construction materials to build the station. No interactive parts designed because outdoor exhibit was subject to elements and potential vandalism. | Specialized software for exhibit design and layout and game design and construction, 3D printer for touchable models, construction tools and materials for exhibit fabrication | Twitter, photo editing software, peer-reviewed literature and publicly available educational resources |
| Time commitment | 132 h: writing content, graphics design, and kiosk construction | 1150 h: developing content, exhibit design and construction, and project management | 52 h/y (2 h/post): writing content, graphic design, posting and responding to comments |
| Collaborators | Albuquerque BioPark and University of New Mexico | Researchers from 4 universities, museum staff, game designers, sculptors, and evaluation consultant | Other Twitter users (e.g., researchers, agencies) |
| Audience reach | 200,000 expected visitors to Tingley Beach annually; mostly local audience | 250,000 expected visitors to NMMNHS annually; state-wide audience, some interstate and international visitors | 12,000 expected Twitter followers, not counting others who may see posts when shared; Great Lakes audience but global in distribution |

[a] In-kind support was estimated from the number of hours contributed by personnel ($20/h).

evaluation, content development, graphic design, fabrication) and managed the project. Additional input was provided by university students and faculty, who developed the computer game and touchable models, and an evaluation consultant, who assessed audience understanding of, and interest in, algal biofuels. Production of the exhibit required coordination of the different contributors and their institutions, and the administrative load was increased by the need to provide regular, detailed reporting to the NM EPSCoR project leaders. In hindsight, we recognize that collaborative exhibit projects of this scale would benefit from a dedicated project manager to guide the process (Hall et al. 2021), and this essential role should be included in budget planning from the beginning.

Despite the challenges, this exhibit was successful in connecting local scientists to the general public, which had advantageous outcomes not only for museum visitors but also for many of the participants, including scientists and museum professionals (Connealy 2018). To help visitors see the human element involved in scientific research, each scientist received training in science communication so they could talk creatively about their work. Just as importantly, professional networks across the state were developed or became stronger: algal researchers learned about their shared interests, museum staff were connected through the broader NM EPSCoR project, and new collaborations emerged between scientists and educators. These networks paved the way for potential future research projects and opportunities for public engagement.

### #25DaysofFishmas

#25DaysofFishmas is an annual Twitter campaign that began in 2016 with the goal of increasing awareness about aquatic biodiversity in the Laurentian Great Lakes, USA, while making people laugh. During this campaign, a different fish species is featured each day during December—wearing a Santa hat, of course (Fig. 2C). The creation of #25DaysofFishmas was inspired by a love of fish and the opportunity to use social media to introduce people to the often-unseen underwater, freshwater world. #25DaysofFishmas has evolved into a forum for mutual learning, where diverse audiences share expertise and experiences while discussing environmental challenges. The campaign is highly interactive, with audiences engaging through retweeting (sharing) and liking posts, as well as replying with their questions or commentary (Table 3). To date, #25DaysofFishmas tweets have been retweeted >8000× and liked >25,000×.

One of the most important lessons learned from this effort is that the interactive and conversational nature of social media influences how audiences engage with scientific content. Scientists best utilize social media for PES when they are perceived as being engaged, e.g., being responsive to audience interests, answering questions rather than only broadcasting scientific facts, and using humor and personal anecdotes (Bauer et al. 2007, Boulianne 2015). The use of social media can make it challenging to establish the trust needed for effective engagement between the scientist and audience, but some trust-building actions a scientist can take include being respectful of the audience, acknowledging other perspectives, admitting knowledge limitations, and publicly correcting their own mistakes (Golladay et al. 2021, Hall et al. 2021).

Benefits of #25DaysofFishmas have emerged for the scientist and audience alike. For the scientist, benefits have included developing the effort into an interdisciplinary chapter of a doctoral dissertation, gaining a professional reputation as an early-career scientist, and expanding networks. Partnering with other Twitter users (e.g., other scientists, agencies) amplified posts and engaged a broader audience than could be achieved with a single Twitter account. The audience benefited by building relationships with scientists and becoming more knowledgeable about research in the Great Lakes. This campaign has nurtured a community of people who care about the Great Lakes and the fish that live there. The success of #25DaysofFishmas has led other science communicators to adopt its model to engage audiences on different topics, including other aquatic organisms such as squids (e.g., #25DaysofSquidmas) and sharks (e.g., #Chondukkah).

## SUGGESTIONS FOR GETTING YOUR FEET WET IN PES

The 3 examples presented here involved different types of PES activities with varying levels of time commitment, funding, and audience reach, thus demonstrating some of the various approaches to PES for both scientists and audiences. The examples also illustrated some of the challenges often faced by scientists engaging in PES, such as the need for adequate communication training, a wide range of logistical and technical know-how requirements beyond common knowledge of the scientific topic, and the time constraints to pursuing a project outside of regular work and research responsibilities. Additionally, successful engagement in all 3 examples relied on more than just the scientist being involved but also active and iterative dialogue with the non-technical audiences. Here we provide suggestions for effectively overcoming some of the common barriers to PES while acknowledging that there is no one-size-fits-all approach.

### Start small

Our examples demonstrate some PES activities that scientists may choose to develop, but it is important to note that these were not the 1st PES activities in which any of the authors had participated. For many scientists, their 1st experience in engaging with non-expert audiences often involves activities requiring less experience, time, and resource commitment, such as talking with friends and family, classroom visits, science fairs, and public lectures (Pham 2016, Sultany and Bixby 2016, Burchell et al. 2017; Table 1). Scientists' ability to participate in PES activities, particularly online activities, is more associated with their self-confidence and willingness to engage rather than formal communication training (Yuan et al. 2019), and participating in PES activities increases the likelihood of a scientist participating again in the future (Poliakoff and Webb 2007, Hara et al. 2019). Social media is used by many scientists for public engagement (Burchell et al. 2017) and is a useful platform to learn by observation. For example, #25DaysofFishmas was informed by watching and interacting with other fish researchers and the general public on Twitter for several months prior to launching the campaign. Smaller-scale PES activities—like participating in a science café organized by others—can be as rewarding and effective as larger, more complex PES activities (Hara et al. 2019) and can be a great way to get your feet wet in PES activities.

Time commitment for PES activities, which is often identified as a challenge because of scientists' multi-pronged professional obligations (TNS-BMRB and PSI 2015, Hopfensperger et al. 2021), can range from short (e.g., public lectures) to more involved (e.g., exhibits). Starting small allows a scientist to constrain the time commitment. In all of our examples, the most time-consuming parts of the work was the development of materials (e.g., graphic panels, 3D models, social media posts). We suggest that time management and planning are essential for success in any PES project. For example, preparing content and scheduling posts in advance is advantageous in social media campaigns. Notably, complex projects (such as the museum exhibit) require a dedicated project manager and we do not recommend this type of activity as a 1st PES project for a scientist.

#### Leverage your skills and resources

Starting small is a good 1st step, but scientists may feel that they lack the training to engage with audiences outside of academia or research laboratories (NSF 2015, TNS-BMRB and PSI 2015, Yuan et al. 2019; Table 2). Scientists do not typically receive formal instruction in science communication or best practices for engaging with non-scientific audiences (The Royal Society 2006, Besley et al. 2015, TNS-BMRB and PSI 2015); however, training opportunities are increasingly offered to researchers by professional societies (Hopfensperger et al. 2021) and organizations such as COMPASS (Smith et al. 2013).

In our examples, we found that we already had skills and resources that allowed us to be successful in PES. In some instances, our prior hands-on experience in PES activities was just as valuable as formal training (cf. Poliakoff and Webb 2007). For example, familiarity with Twitter meant that little initial training was required prior to launching the #25DaysofFishmas campaign. Similarly, prior experience working with designers, educators, and artists to develop museum exhibits (e.g., Burdett 2016) made taking on *Get Going with Green Goop* less intimidating than it may have been without that valuable museum experience. These different projects also reflect different preferences for scientists to interact with audiences or collaborators. On social media, the scientist could rapidly respond to the audience with humor and kindness, whereas developing longer-term interpersonal interactions within the exhibit team was an important part of the process of developing the museum exhibit. To this end, we encourage others to investigate PES options that are most appropriate to their experiences and personal interests as they continue to develop their PES skills and networks (Table 1).

In addition to employing the current skills a scientist might have, it is also essential to leverage any financial and material resources available for PES projects and to seek additional funding at the beginning of a project (TNS-BMRB and PSI 2015). The algae information station and the museum exhibit both leveraged in-house resources for design and construction by working with staff from the BioPark and museum. This type of in-kind support reduced costs significantly. By comparison, #25DaysofFishmas had a far-reaching impact despite the lack of fiscal resources because it was kept simple and focused. For larger, more complex engagement efforts that require significant financial resources, we recommend planning ahead by incorporating these efforts into grant proposals as part of the scope of work (i.e., not treated as an add-on). For example, the cost of the museum exhibit was included in the initial NM EPSCoR Broader Impacts budget. Additionally, the inclusion of PES into Broader Impacts can help prioritize time commitments as part of overall grant activity obligations.

#### Nurture your collaborations

While scientists can start small and use their existing skills and resources to do PES activities on their own, we have found that successful PES often requires collaboration with individuals who have complementary sets of skills and resources (Jacobs et al. 2017, Hara et al. 2019). Collaborations with the non-science community expand the scientist's network beyond the university walls and encourages participation in activities as a community member or civic scientist (Poliakoff and Webb 2007, Burchell et al. 2017). Additionally, building collaborative networks is an important 1st step towards exploring new research topics, provides the ability to mobilize quickly with new partners when opportunities arise (Hall et al. 2021), and promotes creative thinking (Jacobs et al. 2017). In the museum exhibit, scientists worked with new partners and broadened their research networks by connecting with scientists in other disciplines throughout New Mexico. At the BioPark, an established rapport between the researcher and BioPark collaborators made it easier to respond rapidly when there was an opportunity for funding to inform visitors about algae in the ponds.

Working with collaborators can also help scientists find appropriate audiences for PES efforts. Collaborators can help find the target audience and understand their interests (Simon 2016), and working with partners who already have established relationships with different groups (e.g., extension programs, angler groups, local non-profit organizations, museums) can help scientists understand where target audiences seek science content (Hall et al. 2021). Part of the success of #25DaysofFishmas, for example, resulted from reaching out to other Twitter users (e.g., other individual fisheries scientists and Great Lakes science organizations) who shared the tweets with their own audiences.

#### Design for your audience

Once the audience has been identified, successful PES requires consideration of an audience's motivations, values, and beliefs (Simon 2016, Jones and Crow 2017) and ensuring messaging is tailored for the audience, which will help build trust between the scientist and audience so that messaging is tailored appropriately (Dudo and Besley 2016). In the case of #25DaysofFishmas, time was invested up front to determine the target audience, and tweets were tailored appropriately, rather than trying to reach an abstract audience made up of the general public. PES activities may need to be monitored and adjusted in real time. For example, using a variety of outreach techniques over time was most successful in a program to educate anglers about consuming potentially contaminated fishes (Krabbenhoft et al. 2019).

When the audience does not directly interact with the scientist (e.g., as with an exhibit), several mechanisms can be employed to ensure that the final product is both engaging and interesting to the audience. In the *Get Going with Green Goop* example, exhibit design was guided by an extensive front-end and formative evaluation of museum visitors to gauge their level of interest in and understanding of the topic (Connealy 2018). Additionally, conversations between researchers and museum staff helped to determine key messages. Another technique to appeal to a wider audience is to design for multiple points of entry to appeal to different audiences. For example, videos, computer games, touchable elements like specimens or replicas, and web-based resources for further exploration can all be used to connect with different audience members in different ways. The museum field provides considerable insight into designing effective exhibits for interactivity and incorporating the perspective of the non-expert (Simon 2016, Humphrey and Gutwill 2017).

## CONCLUSION

PES does not need to be a large, expensive undertaking to be effective. Because PES is often not defined by traditional academic policies or job descriptions, an individual scientist can tailor their PES activities depending on a number of different factors: their personality and experience, their available resources, and their network. Our examples offer 3 different approaches to PES, and we recognize that there is no one-size-fits-all solution.

We encourage scientists to take opportunities throughout their careers to try out a number of different PES activities with diverse audiences and formats. As scientists learn from their own experimentation in PES, observations should be recorded, evaluated, and—just as importantly—shared (Varner 2014). Ongoing reporting through formal (e.g., conference presentations) and informal (e.g., social media) platforms about PES activities is essential to encourage other scientists to invest time and effort as individuals so that PES can become normalized and increasingly effective for our scientific communities.

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