Theory of Change for Public Engagement with Science

Introduction

Public engagement with science (public engagement) refers to intentional, meaningful interactions that provide opportunities for mutual learning between scientists and members of the public. This document is a first effort to articulate a theory of change for public engagement activities across the spectrum of efforts that occur under this umbrella. This theory of change intends to provide a common framework, language, and research-based foundation for the many professionals involved in public engagement with science activities, and to serve as a starting point to enable scientists, practitioners, and researchers to continually improve and develop collective understanding of effective practices in public engagement with science.

It is important to note that public engagement, as described in this theory of change, is closely related to and influenced by science communication, science education, and other fields. To focus this theory of change, we limited the model to activities that fit the definition above – intentional interactions with opportunities for mutual, two-way learning. That is not to say that other approaches to science communication are unimportant; they are critically important in the larger world. Rather, the purpose of boundary-setting within this document is to focus the public engagement model and articulate theoretical relationships as they apply specifically to efforts within this domain of the science communication universe.

This document is a synthesis of other works prepared and collected by AAAS.[1] While it was designed to build from research as much as possible, it was also informed by public engagement practitioners and real-world experience. It is intended as a summary and overview of what we intend to achieve through public engagement activities.

The Vision: Long-term, Aggregate Impact

To understand the theory of change for public engagement, it is essential to first examine the right-hand side of the Logic Model (Figure 1) – the vision for public engagement. The large-scale goals articulated in this column are cross-cutting scientific and societal impacts envisioned to result from an aggregation, over time, of outcomes of public engagement activities as they interact within individuals and with outside social, political, institutional, and economic influencers. The vision includes change in collective action, policy, research agendas, culture, and workforce. This is the biggest of the big picture; these are aspirational goals that represent the very long-term purpose and potential for aggregate change due to public engagement.

The Theory of Change: How Do We Achieve the Vision?

The rest of the Logic Model, viewed from left to right, depicts the mechanisms of the experiences and interactions that we believe, in aggregate and over the long-term, can lead to this larger vision of public engagement impact. In short, the model depicts how a set of **inputs and resources** are deployed by scientists and public engagement practitioners into a set of **activities with involved participants** (scientists and publics) in order to achieve **outcomes**, or changes in knowledge, attitudes, affect, behavior,

[1] Citations are included, in the form of endnotes, throughout this document. AAAS-commissioned literature reviews are available to provide far greater depth and specificity of research findings only summarized here.

etc. at different time scales. In this narrative discussion of the theory of change, we examine the components of this model to describe its theoretical underpinnings.

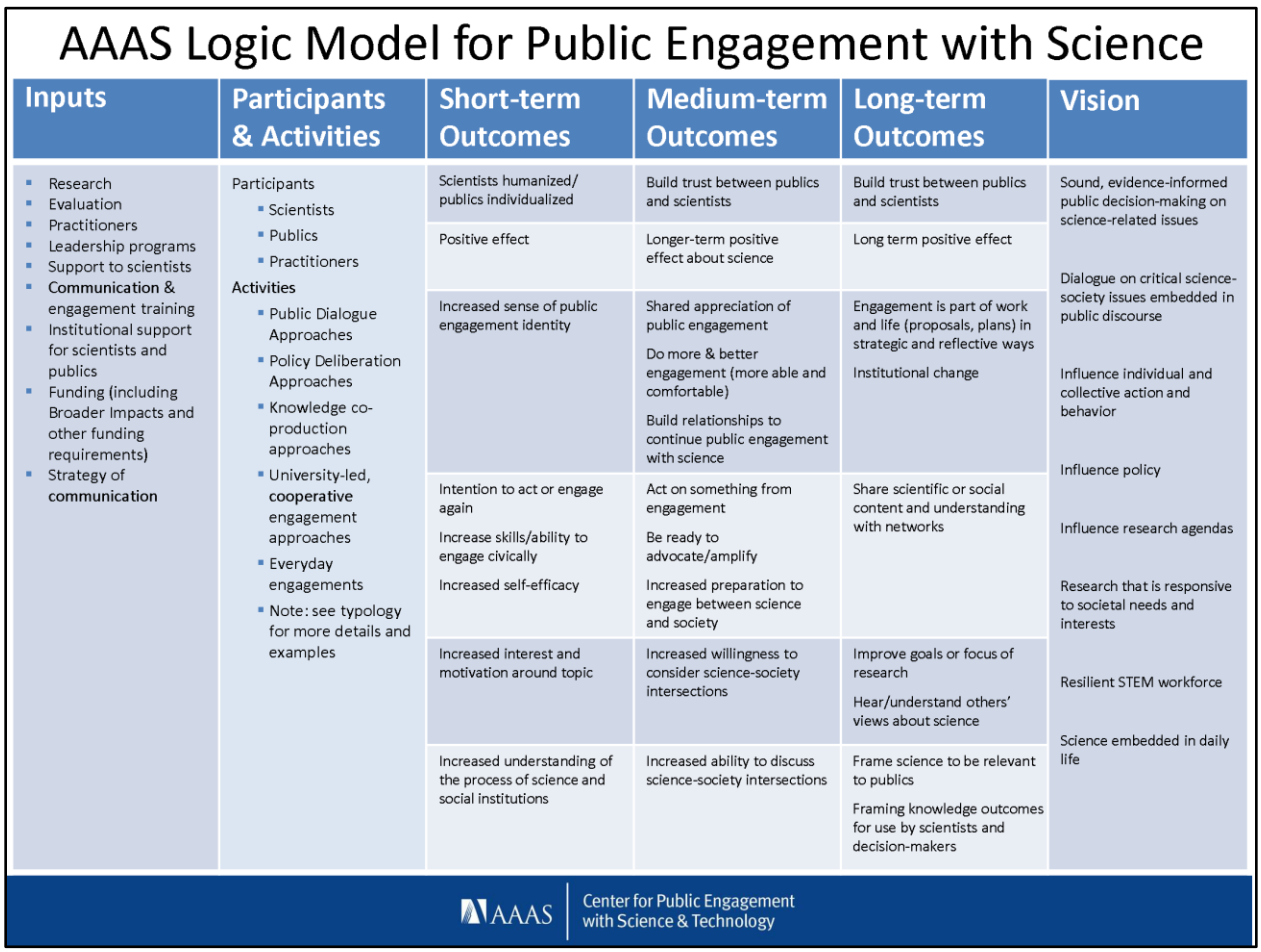

Figure 1: AAAS Logic Model for Public Engagement with Science

Participants: Multiple Actors

Because mutual impacts are fundamental to public engagement, the participants represented in the model include scientists, publics, and practitioners. Public engagement activities involve interaction between these three types of actors in many ways. While the definitions of these actors are not strictly bound (many people identify with multiple roles), functional definitions are helpful to interpret this theory of change[1]:

- **Scientists:** Active researchers from any domain of the sciences (natural, physical, social, etc.), inclusive of applied fields, such as engineering;
- **Publics:** Individuals who operate primarily outside of the practice of science, including the "general public" and highly specialized publics, including policy makers, business leaders, community leaders, and others with extensive expertise in non-science domains;
- **Practitioners:** Those with expertise in conducting public engagement activities; many, but not all, identify with other professions (such as informal science education).

Public engagement is about relationships between these actors, making it important to consider that each group begins from a different set of motivations and perspectives. Multiple lines of research with scientists, for instance, show a very strong effect of an ingrained idea of the "deficit model" of communication, which presumes the public lacks knowledge that a scientist will supply. While communication research has routinely shown this approach to be ineffective, "informing the public" and/or "defending science from misinformation" continue to be at the top of scientists' most prioritized communication goals, predictors of valuing outreach, and desires for communication training.[2] In fact, the perceived importance of "informing publics" is so ingrained that its prioritization is generally unaffected by other attitudinal, behavioral, or demographic factors.[3] While this is a pervasive incoming perspective, research also shows other factors related to public engagement with science participation, including commitment to the public good, feelings of ability to be successful at outreach, and belief in the effectiveness of outreach.[4] Interestingly, evidence does not indicate an influence of demographic factors (such as age, discipline, or career stage).

Among publics, a wealth of research has shown the complex relationships between attitudes, knowledge, and perspectives related to scientific issues. Most notably, many studies have shown that the relationship between factual knowledge and attitudes on a scientific issue is very weak – and in some cases reversed, where greater scientific knowledge is related to negative attitudes about an issue.[5] This points to the need for an alternative to the deficit model in public engagement, reflecting real world conditions where publics' interpretations about implications of science are tied to mental models, personal identity (i.e., political affiliation or religiosity), and other factors.[6] Another significant concern in public engagement is the potential effects of a self-selection bias among publics. Research shows that those who engage are primarily self-selected (due to the free-choice nature of public engagement activities) and tend to have prior interest in science and/or policy, hold specific interest or a pre-existing position on a particular issue, and/or be of higher socioeconomic status and education than is representative of the public at large.[7]

Finally, some work has highlighted the differences in perspectives between scientists, practitioners, and scholars of public engagement,[8] noting the conflict between deficit and democratic-engagement models (held by scientists and practitioners/scholars, respectively). This foregrounds differences in how these three stakeholder groups perceive and understand the public engagement literature, where different worldviews, jargon, and dissemination of recommendations are common and gaps not yet bridged.

Activities: Five Types of Engagement

Synthesis of literature and practice has revealed a general typology of five types of public engagement activities,[9] within which there are further variations of specific programmatic approach and formats. While the types may not be mutually exclusive, this framework delineates several critical pathways for public engagement activities, each of which provides a unique set of opportunities, strengths, and constraints. In a very brief summary, the five types are:

- **Deliberative** – usually tied to policy and directly addressing issues at the intersection of science and society; outcomes directly tied to policy action are most common;
- **Dialogue** – somewhat more process-based, with the act of interaction driving its definition; outcomes tend toward more personal-level changes in interest, affect, or knowledge;
- **Knowledge Co-Production** – emphasis on the process of science; outcomes relate to building scientific skills in publics and bringing non-expert perspectives to research;
- **University-Led Cooperative** – focuses on professional communities and how university researchers can provide expert consultation and collaboration to support their efforts;

- **Informal** – informal one-on-one interactions in daily life between scientists and publics; primarily neglected in the literature, this category represents (likely) the most frequently experienced and least studied type of engagement.

It is important to note that this typology transcends the various communication channels; each activity-type can occur face-to-face or via mediated (including online) mechanisms in a variety of ways. As the presence of social media proliferates in the daily lives of publics and scientists, the potential and role of engagement within the digital space is expanding, with a dearth of research specifically on activities in the digital environment[10] and how they may contrast or confirm what is known about face-to-face environments.

The variety in this typology highlights the need to consider carefully which public engagement approach is best-suited to one's goals, reflecting on the strengths and outcomes emphasized within each type. By including the range of activity-types, the theory of change underscores that there is no programmatic "silver bullet" for achieving the long-term vision of societal change within public engagement. Rather, a complementary suite of activities, combined with intentional goal-setting and training toward related communication skill sets, is needed.[11]

The Deficit Model

In principle, engagement activities involve two-way interaction and mutual learning, in contrast with activities defined by the "deficit model," described earlier. In practice, however, the two approaches are rarely mutually exclusive. Reviews note that a majority of public engagement activities still have as their "backbone" elements of the deficit model, with outcomes of knowledge transfer,[12] and scientists tend to prioritize communication goals that favor the deficit model (e.g., defending science and informing publics) over goals of trust and perspective-seeking.[13] As we refine this theory of change over time, it may be necessary to explore the boundaries of what defines public engagement activities, including the tensions between their two-way communication goals and the practical use of unidirectional, deficit model approaches.

Outcomes: Achieving Change

Finally, the model depicts six horizontal bands of outcome areas. As you move from left to right within each outcome band, the outcomes progress from short-term impact on individuals (happening immediately or very close in time to the engagement activity) to longer-term impacts that are more collective and, ultimately, societal (including changes within science itself).

As with the public engagement activities in this model, the outcomes represent a continuum of possible impacts that reflect a spectrum of potential goals. This is the model for a collective set of activities; it is not suggesting that any one public engagement activity address every outcome in this framework, but that each activity addresses a selection of outcomes most pertinent to its programmatic objectives. The outcomes in the theory of change range from affective experience to skills and empowerment to behavior and decision-making, following from recommendations in literature examining theory and practice in public engagement.[14]

Perceptions and Trust

The first band of outcomes in the model focuses on building mutual trust between scientists and publics, beginning with humanizing of scientists and individualization of publics. Trust has been defined by three dimensions, including beliefs about integrity, dependability, and confidence.[15] There is abundant research indicating the critical nature of trust-building in public engagement, including its role as a precursor to achieving other outcomes. In settings from deliberative forums to citizen science, the development of publics' trust in scientists and the scientific process were important outcomes, particularly in instances

that dealt with controversial topics.[16] The idea in the theory of change is that publics first view scientists as relatable people and fellow citizens. With time and relationship-building, publics come to identify scientists (and scientific institutions) as trusted and respected sources on par with the trust placed in family, friends, or other respected peers. Research shows trust in scientists is one of the strongest correlates of other positive attitudes toward science.[17] Further, when looking at longer-term, policy implications, it has been found, although not conclusively, that the results of public engagement activities can be deemed more legitimate by decision-makers when it is evident the public engagement process was representative and a credible expression of public sentiment;[18] this suggests the need for a process that fosters mutual trust. In addition, online engagement appears to be fruitful ground for further advancement. When considering theory about the role trust and credibility play within communication best practices,[19] combined with the affordances provided by social media, it suggests great potential for online platforms to be critical tools in achieving outcomes of humanizing scientists and increasing credibility,[20] although little empirical documentation of outcomes from social media outcomes have yet been made.

On the flipside, there is a clear gap between research showing the importance of trust, and scientists' perceptions of what is important in outreach or engagement efforts. Research shows that scientists least prioritize communication goals and training opportunities that focus on trust-building.[21] This suggests that scientists who enter the public engagement sphere may first need to achieve some degree of attitudinal change around the importance of trust as an outcome (and develop trust in public engagement practitioners) to fully realize this theory of change. The intent is that, through engagement, scientists will come to differentiate the "general public," developing a more nuanced understanding of the diversity of perspectives, worldviews, and interests that non-scientists hold. With time, it is anticipated that scientists will begin to trust in the capacity of the public (and public/social institutions) to be active and robust partners in the advancement of science that benefits society. This area, however, has been thus far understudied in the public engagement literature.

Affect and Interest

The second outcome band in the model reflects impacts that are personal and focused on feelings about science and science experiences, and depicting how those might impact attitudes about science over time. Evidence from a number of types of public engagement activities (citizen science projects, science festivals, science cafés, etc.) indicate that publics are motivated by and achieve these positive, affective outcomes through interacting with scientists and science research in ways that are exciting, relaxed, social, and low-pressure. Studies of these activities show, for example, citizen science projects that build audience interest by being "easy, fun, and social"; science festivals promoting interest and curiosity about science through experiences that are designed to be novel and captivating; and science café attendees' appreciation of intimate and social settings, relaxed atmosphere, and accessibility of experts.[22] For scientists, affect is about enjoying public engagement and appreciating public inputs/perspectives.

These outcomes are generally documented as immediate impacts, although some research has indicated that interpersonal science-focused conversations are linked with increased concern about an issue,[23] which suggests potential for longer-term impact. However, there is limited data on longer-term affect toward science as a result of public engagement, with existing research indicating a lack of evidence of any strong factor that affects large-scale positive views of science, including informal science experiences.[24] Among scientists, however, research has shown that scientists who express higher personal enjoyment from engagement are also more likely to prioritize trust-building as a goal,[25] indicating presence and potential importance in affective outcomes for scientists. Program evaluation from a number of public engagement activities has also shown that the majority of scientists who do this type of work truly enjoy the experience, whether it is the interaction with publics, the reward of giving back to their community, enjoying the social interaction with other scientists engaged in public engagement, or the sense of having made a difference in society.[26] The effect of self-selection is likely at play, with scientists gravitating

toward the type of engagement experiences that are most rewarding for them in terms of the audience, nature of interaction, and the types of outcomes that are achieved. Finding the right "fit" between individual and engagement opportunity is an important piece of the model at a program level.

Identity and Skill

The third outcome band focuses on the development of identity and skills used within public engagement activities. Inherent in the outcomes articulated in this set is the idea that both actors (scientist and public) grow in their relationship-building with one another, but also aligned toward the value of public engagement as a practice. This system follows a trajectory in which the development of individual- and community-level identity shifts toward more plentiful and more effective public engagement activity and, ultimately, institutional changes and priorities that incorporate these principles.

Among scientists, the research provides evidence to support this trajectory of change, in particular relationships between the amount of engagement activity by a scientist and his/her sense of her own ability to engage. While the direction of the relationship is not clear (i.e., whether the act of engaging increases sense of skill or the sense of skill leads to more time in engagement work), the data do show that the more a scientist perceives him/herself to be good at a particular type of communication, the more likely he/she is to prioritize it among other goals.[27] Some public engagement literature has asserted that the act of dialogue between scientists and publics can be considered an important outcome itself in some contexts (as opposed being a mechanism toward a more policy-oriented outcome), including the contention that they offer communication skill- and experience-building for scientists.[28] An implication here is that familiarity and practice is necessary to make the experience of public engagement dialogue a norm. When it comes to examining institutional change, there is a lack of research and evidence on this longer-term outcome in the literature thus far.

Behavior and Skill

The next outcome band depicts a set of outcomes that collectively contribute to behavior change, built upon frameworks about the sources of behavior change from social science research (e.g., the theory of planned behavior). These outcomes highlight the importance that public engagement activities first develop changes in intention to act, skills, and self-efficacy (or the perception of one's ability to succeed at a task), all of which contribute to longer-term behavior change, in addition to continual skill and self-efficacy growth.

Research with scientists and their likelihood of demonstrating engagement behaviors has shown repeatedly that there is a correlation between engagement behavior and internal efficacy (perception about one's own ability), as well as external efficacy (perception that the mode of engagement can be effective).[29] This research has asserted that scientist training efforts might have the greatest impact on promoting engagement behaviors in the long-term by focusing on building internal and external efficacy.

Research on the promotion of behavior change among public audiences is less conclusive. While some evidence shows that a sense of self-efficacy around a topic (such as climate change) is essential to promoting engagement and action among members of the public,[30] other studies of public engagement activities have shown a lack of evidence of long-term change in civic action.[31] In the online space, there is a lack of empirical research on the degree to which (if at all) social media-based engagement is achieving larger goals of encouraging decision-making, dialogue, or policy direction.[32] Once again, this outcome band is likely influenced by the overarching importance of the development of trust (discussed earlier), which has been linked to taking action.[33]

Interest and Motivation

The band of outcomes focuses on the influence of two-way interaction on becoming more familiar with a breadth of perspectives and worldviews on science-society intersections. These outcomes indicate

profound changes in perspective and motivation to take a more inclusive worldview, and they include a growth of mutual appreciation, respect, and value for the different actors – with the value of inclusivity of perspectives becoming core to practice as professionals or citizens.

Research supports this through repeated findings that scientific knowledge alone is insufficient to achieve integration and use of science by individuals or institutions. Contextualization of science within personal and sociocultural contexts (and expertise) of publics is essential. Research points to the need for scientists (and public engagement practitioners) to develop a deep understanding of what motivates publics and to balance stakeholder and scientific agendas. To do this, the literature stresses the importance of forging interpersonal relationships, for the participants to cultivate an openness to understanding one another, and for the scientific perspectives to incorporate and respect local and experiential knowledge of publics.[34] What is less known are the mechanisms by which these perspectives and value sets are best encouraged among audiences (scientific or public) that may be more inclined toward or familiar with a deficit model of interaction.

Contradictions and barriers to these goals, however, are well known, particularly in regard to highly charged issues. For instance, while some research suggests that "talking about science" has many civic benefits, substantial research has shown that "discussing politics with like-minded others" can greatly increase polarization on science issues.[35] This suggests the importance of careful construction of engagement opportunities to avoid the latter scenario, since polarization is contradictory to the openness of perspectives inherent in these public engagement goals.

Perspective and Mutual Learning

The final band of outcomes in the theory of change focuses explicitly on mutual learning between scientists and publics, with the idea that each perspective can learn a great deal from the knowledge, expertise, and concerns of the other(s). An inherent component is that the actors in an engagement are growing in their ability to understand, frame, and discuss their knowledge in ways that are relevant to the other actors (i.e., how science is relevant to publics, and how public knowledge and social concerns are relevant to research directions).

This goal is a lynchpin of the theory of change for public engagement, central in much of the theory behind program design. Yet, as one of its more aspirational and challenging elements, the research base for how and when mutual learning is achieved is less clear. In general, there is a lack of systematic evidence demonstrating how and under what conditions public engagement activities have influenced policy, with applied research pointing to a number of contextual factors that must be attended to in order for mutual learning to have greatest potential impact on a complex societal issue – from framing, to timing, to appropriate scale, to the need for ongoing interaction and relationship-building.[36]

Further, research with scientists reveals that there are a number of perceptual barriers to overcome in order to fully achieve these outcomes. In particular, scientists have shown discomfort with the idea of framing messages to resonate with existing views or values, with scientists questioning whether it was ethically appropriate to do so.[37] In general, this research suggests that communication goals and training programs that focus on responsiveness, resonance with values, and mutual learning are not common or comfortable within much of the science community. From the viewpoint of this research, a key component for achieving this set of outcomes with scientists will be developing new understanding of the intent and ethics of framing as a communication strategy, in a way that resonates with a scientific worldview.

Conclusion

This theory of change presented a brief overview and explanation of the public engagement logic model, including some of the theoretical and applied research that underpins its mechanisms, relationships, and assumptions. The hope of this document is to give all of the public engagement actors – practitioners, scientists, publics, and researchers – some common language, an applicable framework, and an understandable rationale behind the collective vision of impact from public engagement with science efforts worldwide. This theory will be tested through evaluation of public engagement activities and will be updated as appropriate.

---

[1] Braha, 2015
[2] Besley, et al., 2013; Besley, et al., 2015; Dudo & Besley, 2016
[3] Dudo & Besley, 2016
[4] Besley, et al., 2013
[5] E.g., Allum et al, 2008; Pew, 2015; Kahan, et al., 2012; Kahan, 2015; Gauchat, 2015; Nisbet, 2005; Brossard et al., 2008 (cited in Nisbet & Markowitz, 2016)
[6] E.g., Kahan, 2011; Scheufele, 2013 (cited in Braha, 2015 & Nisbet & Markowitz, 2016)
[7] E.g., Trousset, et al., 2015 (cited in Nisbet & Markowitz, 2015); Scheufele, 2013 (cited in Nisbet & Markowitz, 2016)
[8] E.g., Salmon, et al., 2015 (cited in Nisbet & Markowitz, 2015)
[9] Nisbet & Markowitz, 2015; Storksdieck, et al., 2016
[10] Yeo, 2015
[11] Dudo & Besley, 2016; Besley, et al., 2015
[12] Brossard & Lewenstein, 2009 (cited in Nisbet & Markowitz, 2015)
[13] Dudo & Besley, 2016
[14] E.g., Brossard & Lewenstein, 2009; Einsiedel, 2014 (cited in Nisbet & Markowitz, 2015)
[15] National Academies, 2015 (cited in Nisbet & Markowitz, 2016)
[16] E.g., Young, et al., 2013; Bartels, et al., 2013; Buhr & Wibeck, 2014; Longstaff & Secko, 2014; Shirk, et al., 2012; Diehl, et al., 2015; Wilke & Morton, 2015; Furman, et al., 2014 (cited in Nisbet & Markowitz, 2015)
[17] E.g., Sturgis & Allum, 2004 (cited in Nisbet & Markowitz, 2016)
[18] Emery, et al., 2015 (cited in Nisbet & Markowitz, 2015)
[19] E.g., Heath & Heath, 2007; Keitzmann, et al., 2011 (cited in Yeo, 2015)
[20] Yeo, 2015
[21] Dudo & Besley, 2016; Besley, et al., 2015
[22] E.g., Dickinson, et al., 2012; Jensen & Buckley, 2014; Navid & Einsiedel, 2012 (cited in Nisbet & Markowitz, 2015)
[23] E.g., Eveland & Cooper, 2013 (cited in Nisbet & Markowitz, 2016)
[24] Besley, 2015
[25] Dudo & Besley, 2016
[26] E.g., Sickler, 2014; Sickler & Hayde, 2014; Sickler, et al., 2011
[27] Dudo & Besley, 2016
[28] E.g., Einsiedel, 2014 (cited in Nisbet & Markowitz, 2015)
[29] Besley, 2015; Besley, et al., 2015
[30] E.g., Feldman & Hart, 2016 (cited in Nisbet & Markowitz, 2016)
[31] E.g., Guston, 2014 (cited in Nisbet & Markowitz, 2015)
[32] Yeo, 2015
[33] E.g., Leiserowitz, et al., 2015 (cited in Nisbet & Markowitz, 2016)
[34] E.g., Bartels, et al., 2013; Furman et al., 2014 (cited in Nisbet & Markowitz, 2015); SteelFisher, et al., 2015; (cited in Nisbet & Markowitz, 2016)
[35] E.g., Goidel & Nisbet, 2006; Binder, et al., 2011 (cited in Nisbet & Markowitz, 2016)
[36] E.g., Guston, 2014; Emergy, et al., 2015 (cited in Nisbet & Markowitz, 2015)
[37] Besley, et al., 2015; Dudo & Besley, 2016

Original AAAS Source Material

American Association for the Advancement of Science (AAAS). (2016). *Logic Model for Public Engagement with Science*. Washington, DC: AAAS.

Besley, J. C. (2015). Predictors of perceptions of scientists: Comparing 2001 and 2012. *Bulletin of Science, Technology & Society,* 1-12.

Besley, J. C., Dudo, A., & Storksdieck, M. (2015). Scientists' views about communication training. *Journal of Research in Science Teaching, 52*(2): 199-220.

Besley, J. C., Oh, S. H., & Nisbet, M. (2013). Predicting scientists' participation in public life. *Public Understanding of Science, 22*(8): 971-987.

Braha, J. (2015). Public engagement with science and informal science education. *Informal Learning Review,* November/December 2015: 18-23.

Dudo, A., & Besley, J. C. (2016). Scientists' prioritization of communication objectives for public engagement. *PLoS ONE, 11*(2).

Nisbet, M. C. & Markowitz, E. (2015). *Public Engagement Research and Major Approaches*. Washington, DC: AAAS.

Nisbet, M. C. & Markowitz, E. (2016). *Americans Attitudes about Science and Technology: The Social Context for Public Communication*. Washington, DC: AAAS.

Storksdieck, M., Stylinski, C, & Bailey, D. (2016). *Typology for Public Engagement with Science: A Conceptual Framework for Public Engagement Involving Scientists*. Corvallis, OR: Center for Research on Lifelong STEM Learning.

Yeo, S. K. (2015). *Public Engagement with and Communication of Science in a Web-2.0 Media Environment*. Washington, DC: AAAS.

References within AAAS Source Material

Allum, N., Sturgis, P., Tabourazi, D., & Brunton‐Smith, I. (2008). Science knowledge and attitudes across cultures: A meta‐analysis. *Public Understanding of Science, 17*(1), 35‐54.

Bartels, W. L., Furman, C. A., Diehl, D. C., Royce, F. S., Dourte, D. R., Ortiz, B. V., ... & Jones, J. W. (2013). Warming up to climate change: a participatory approach to engaging with agricultural stakeholders in the Southeast US. *Regional Environmental Change, 13*(1), 45-55.

Binder, A. R., Scheufele, D. A., Brossard, D., & Gunther, A. C. (2011). Interpersonal amplification of risk? Citizen discussions and their impact on perceptions of risks and benefits of a biological research facility. Risk Analysis, 31(2), 324---334.

Brossard, D., & Lewenstein, B. V. (2009). A Critical Appraisal of Models of Public Understanding of Science: Using Practice to Inform Theory. In L. Kahlor & P. Stout (Eds.), *Communicating Science: New Agendas in Communication* (pp. 11-39). New York: Routledge.

Brossard, D., Scheufele, D. A., Kim, E., & Lewenstein, B. V. (2008). Religiosity as a perceptual filter: Examining processes of opinion formation about nanotechnology. *Public Understanding of Science.*

Buhr, K., & Wibeck, V. (2014). Communication approaches for carbon capture and storage: Underlying assumptions of limited versus extensive public engagement. *Energy Research & Social Science, 3*, 5-12.

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., ... & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment, 10*(6), 291-297.

Diehl, C., et al. (2015). Toward engagement in climate training: Findings from interviews with agricultural extension professionals. *Journal of Rural Social Sciences 30*(1), 25-50.

Einsiedel, E. F. (2014). Publics and their participation in science and technology. *Routledge Handbook of Public Communication of Science and Technology,* 125.

Emery, S. B., Mulder, H. A., & Frewer, L. J. (2015). Maximizing the policy Impacts of public engagement: A European study. *Science, Technology & Human Values, 40*(3), 421-444.

Eveland, W. P., & Cooper, K. E. (2013). An integrated model of communication influence on beliefs. *Proceedings of the National Academy of Sciences, 110*(Supplement 3), 14088-14095.

Feldman, L., & Hart, P. S. (2016). Using political efficacy messages to increase climate activism: The mediating role of emotions. *Science Communication, 1*, 99‑127.

Furman, C., Roncoli, C., Bartels, W., Boudreau, M., Crockett, H., Gray, H., & Hoogenboom, G. (2014). Social justice in climate services: Engaging African American farmers in the American South. *Climate Risk Management, 2*, 11-25.

Gauchat, G. (2015). The political context of science in the United States: public acceptance of evidence‑based policy and science funding. *Social Forces*, sov040.

Goidel, K., & Nisbet, M. (2006). Exploring the roots of public participation in the controversy over embryonic stem cell research and cloning. Political Behavior, 28(2), 175---192.

Guston, D. H. (2014). Building the capacity for public engagement with science in the United States. *Public Understanding of Science, 23*(1), 53-59.

Heath, C., & Heath, D. (2007). *Made to stick: Why some ideas survive and others die*. New York: Random House.

Jensen, E., & 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.

Kahan, D. M. (2015). Climate-science communication and the measurement problem. *Political Psychology, 36*(S1), 1‑43.

Kahan, D. M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L. L., Braman, D., & Mandel, G. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nature Climate Change, 2*(10), 732-735.

Kahan, D., et al. (2011). The tragedy of the risk-perception commons: Culture conflict, rationality conflict, and climate change. *Temple University Legal Studies Research Paper No. 2011-26; Cultural Cognition Project Working Paper No. 89; Yale Law & Economics Research Paper No. 435; Yale Law School, Public Law Working Paper No. 230.*

Kietzmann, J. H., Hermkens, K., McCarthy, I. P., & Silvestre, B. S. (2011). Social media? Get serious! Understanding the functional building blocks of social media. *Business Horizons, 54*(3), 241-251.

Leiserowitz, A., Maibach, E., Roser-Renouf, C., Feinberg, G., & Rosenthal, S. (2015). *Climate change in the American mind: March, 2015*. Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication.

Longstaff, H., & Secko, D. M. (2014). Assessing the quality of a deliberative democracy mini-public event about advanced biofuel production and development in Canada. *Public Understanding of Science*, 0963662514545014.

National Academies. (2015). *Trust and Confidence at the Interfaces of the Life Sciences and Society: Does the Public Trust Science? A Workshop Summary*. Washington, DC: National Academies.

Navid, E. L., & Einsiedel, E. F. (2012). Synthetic biology in the Science Café: what have we learned about public engagement?. *Journal of Science Communication, 11*, 4.

Nisbet, M. C. (2005). The competition for worldviews: Values, information, and public support for stem cell research. *International Journal of Public Opinion Research, 17*(1), 90-112.

Pew Research Center (2015). *Americans, Politics, and Science Issues*. Washington, DC.

Salmon, R. A., Priestley, R. K., & Goven, J. (2015). The reflexive scientist: an approach to transforming public engagement. *Journal of Environmental Studies and Sciences,* 1-16.

Scheufele, D. (2013). Communicating science in social settings. *Proceedings of the National Academy of Sciences, 110*, 14040-14047.

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., ... & Bonney, R. (2012). Public participation in scientific research: a framework for deliberate design. *Ecology and Society, 17*(2), 29.

Sickler, J. (2014). *Science & Engineering Ambassadors Program: Formative Evaluation Findings*. Columbus, OH: Lifelong Learning Group. [unpublished report]

Sickler, J. & Hayde, D. (2014). *Evaluation of the Science & Entertainment Exchange: Findings from Entertainers and Scientists.* Columbus, OH: Lifelong Learning Group. [unpublished report]

Sickler, J., Foutz, S., Ong, A., Storksdieck, M., & Kisiel, J. (2011). *Portal to the Public Guiding Framework: Determining the Value of a Model for Scientist-Visitor Interactions*. Edgewater, MD: Institute for Learning Innovation. [unpublished report]

SteelFisher, G. K., Blendon, R. J., & Lasala-Blanco, N. (2015). Ebola in the United States: Public reactions and implications. *New England Journal of Medicine, 373*(9): 789-791.

Sturgis, P. & Allum, N. (2004). Science in society: Re-evaluating the deficit model of public attitudes. *Public Understanding of Science, 13*(1), 55-74.

Trousset, S., Gupta, K., Jenkins-Smith, H., Silva, C. L., & Herron, K. (2015). Degrees of engagement: Using cultural worldviews to explain variations in public preferences for engagement in the policy process. *Policy Studies Journal, 43*(1), 44-69.

Wilke, A. K., & Morton, L. W. (2015). Climatologists' communication of climate science to the agricultural sector. *Science Communication*, 1075547015581927.

Young, J. C., Jordan, A., Searle, K. R., Butler, A., Chapman, D. S., Simmons, P., & Watt, A. D. (2013). Does stakeholder involvement really benefit biodiversity conservation? *Biological Conservation, 158*, 359-370.