Essay

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The lure of rationality: Why does the deficit model persist in science communication?

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Abstract

Science communication has been historically predicated on the knowledge deficit model. Yet, empirical research has shown that public communication of science is more complex than what the knowledge deficit model suggests. In this essay, we pose four lines of reasoning and present empirical data for why we believe the deficit model still persists in public communication of science. First, we posit that scientists' training results in the belief that public audiences can and do process information in a rational manner. Second, the persistence of this model may be a product of current institutional structures. Many graduate education programs in science, technology, engineering, and math (STEM) fields generally lack formal training in public communication. We offer empirical evidence that demonstrates that scientists who have less positive attitudes toward the social sciences are more likely to adhere to the knowledge deficit model of science communication. Third, we present empirical evidence of how scientists conceptualize "the public" and link this to attitudes toward the deficit model. We find that perceiving a knowledge deficit in the public is closely tied to scientists' perceptions of the individuals who comprise the public. Finally, we argue that the knowledge deficit model is perpetuated because it can easily influence public policy for science issues. We propose some ways to uproot the deficit model and move toward more effective science communication efforts, which include training scientists in communication methods grounded in social science research and using approaches that engage community members around scientific issues.

Keywords

knowledge deficit model, policy, public, science communication, social sciences, STEM

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1. Introduction

In a democratic society, citizens are implicitly asked to make decisions about the funding and regulation of science and technology. For the advancement of science in society, publics must, broadly speaking, be supportive of scientists and their work. In the United States, citizens are divided over many scientific issues, often leading to policy inaction. Climate change and energy issues, for example, have galvanized public audiences, and we see widening divides in public opinion toward these and many other scientific issues (Pew Research Center, 2011a, 2011b, 2014b).

Science communication is one technique being used in the effort to bridge such divides. Burns et al. (2003) recognize five main purposes of science communication: awareness, enjoyment, interest, opinion formation, and understanding. In this essay, we look at three of these purposes (awareness, understanding, and opinion formation) in the context of science communication with lay audiences from scientists and science communicators.

Historically, science communication has been predicated on the assumption that ignorance is the basis of a lack of societal support for various issues in science and technology. This model, known as the knowledge deficit model of science communication, has led much of the subsequent research in the field to explore the concept of science literacy. One particularly influential definition of science literacy, proposed in the 1980s, included three dimensions: (1) an understanding of basic scientific words and facts, (2) an understanding of the general scientific process, and (3) an understanding of policy issues related to science (Miller, 1983). Based on these dimensions, the majority of adults in the United States were found to be scientifically *illiterate* (Miller, 1983), which resulted in a call for more science and technology education and communication for public audiences. In the past several decades, the concept of science literacy has been hotly debated and fundamentally reconsidered. For example, Feinstein (2011) argues that the term science literacy has been reduced to a hollow catchphrase and one that is ultimately salvageable if we "make it into a meaningful educational goal instead of a mere slogan—by redefining it according to research on the actual uses of science in daily life" (p. 183).

While Feinstein (2011) and others have argued for alternative approaches to science education and communication, many efforts to increase science literacy rest on Miller's (1983, 1998) formative work. Miller's formative work led to greater awareness of the need for public engagement with and communication of science and mobilized the scientific community to fill the deficit in knowledge among public audiences. Unfortunately, this approach assumes that scientific knowledge communicated to publics stands alone to encourage understanding and support of science. The interpretation of these facts is assumed to be identical for all members of the public. An assumption of rational reasoning underlies this strategy of public communication. If individuals interpret information in a rational and objective manner, many experts believe that the conclusions of public audiences will be supportive of science. This notion of the knowledge deficit model is epitomized in the phrase "To know science is to love it" (Turney, 1998).

Yet, empirical research has shown that public communication of science is more complex than what the knowledge deficit model suggests (e.g. Brossard et al., 2009; Davies, 2008; Nisbet and Scheufele, 2009; Sturgis and Allum, 2004; Yeo et al., 2015). In this essay, we pose four lines of reasoning and present empirical data for why the deficit model persists in science and its public communication.

First, scientists are trained to be objective decision makers. The scientific endeavor is underscored by rational processing of information to draw conclusions based on empirical information. We posit that such training results in the belief that public audiences can and do process information in a similar manner. Second, the persistence of this model may be a result of current institutional structures. Many graduate education programs in science, technology, engineering, and math (STEM) fields generally lack formal training in public communication. We offer empirical evidence

that demonstrates that scientists who have less positive attitudes toward the social sciences are more likely to adhere to the knowledge deficit model of science communication. This has implications for how they understand and interpret empirical research in science communication, which can provide insights into how scientists view public communication and best practices in this area. This, in turn, affects the formation of public attitudes toward science. Third, we present empirical evidence of how scientists conceptualize "the public" and link this to attitudes toward the deficit model. We find that perceiving a knowledge deficit in the public is closely tied to scientists' perceptions of individuals who comprise the public. Finally, we argue that the knowledge deficit model is perpetuated because it can easily influence public policy for science issues. Addressing the multitude of variables that impact public attitudes toward science is more complex than a one-size-fits-all approach that targets public knowledge levels, which makes the deficit model particularly appealing from a policy formation standpoint.

Before a detailed discussion of these four lines of reasoning, it is important to note that we do not aim to discount the role of knowledge in public understanding of science. Knowledge can be, and often is, an important factor in public attitudes toward science and technology. In fact, knowledge has been associated with elevated levels of support for some issues, although it often takes a backseat to trust and other predispositions (e.g. Allum et al., 2014; Brossard et al., 2009; Mou and Lin, 2014; Sjöberg and Drottz-Sjöberg, 1991). Perhaps more importantly, our goal is not to suggest that the only rationale for scientists to communicate their research to public audiences is to garner support for their work. Scientists are motivated to engage in public communication by a range of factors, both intrinsic and extrinsic, and the benefits of such communication—for example, creating an informed citizenry able to participate in the scientific debates of the day—are often outside of narrow deficit model thinking. Instead, we hope to draw attention more generally to why scientists may still adhere to the deficit model for two important reasons. First, insights into why this model persists will enable scholars to advance our understanding and move beyond this knowledge deficit. We also hope that this essay, in combination with others in this special issue, will further expand the ways in which scientists and other communicators interact with public audiences.

2. Scientists are trained to process information in a rational manner

In a model democracy, citizens would be rational thinkers. This notion of an objective, rational citizenry is grounded in the political systems envisioned by Plato and Aristotle. Rational choice theory subsequently developed in fields such as political science and economics as a framework for understanding individual and collective behavior (e.g. Downs, 1957; Gely and Spiller, 1990; Iannaccone, 1995; Simon, 1955; Tversky and Kahneman, 1986). As expected, one key assumption of rational choice theory is rational reasoning. Simply put, the theory posits that individuals make intentional decisions by weighing costs and benefits of options and information to maximize individual advantage (Becker, 1976; Downs, 1957; Friedman, 1953). Yet, the reality is clearly far from this ideal. As Lodge and Taber (2013) point out, we are "rationalizing, rather than rational, citizens" (p. 1). Rational thought and objectivity also guide the scientific endeavor. In fact, the training of scientists is rooted in it; scientific success and credibility are linked to the ability to "abandon or modify accepted conclusions when confronted with more reliable experimental evidence" (American Association of Physics Teachers, 1999: 659). In other words, knowledge trumps all in the realm of science.

However, because we are confronted daily with more information than we can handle and have little expertise about, it is unsurprising that non-expert decisions are often made through heuristics or

mental shortcuts. This phenomenon has been demonstrated in a variety of fields, including economics (e.g. Kahneman, 2011), political science (e.g. Taber and Lodge, 2006), and science communication (e.g. Brossard et al., 2009). Contemporary science is more complex and embedded in society than ever before. Modern science is characterized by its interdisciplinary nature, which highlights uncertainty and high stakes with regard to ethical, legal, and social implications (ELSI; Funtowicz and Ravetz, 1993). Moreover, science, politics, and society are increasingly intertwined; for evidence of this, we need to look no further than legislation such as the High Quality Research Act in the United States, which aims to reduce the autonomy of the National Science Foundation (NSF), forcing the agency to only allocate funds toward projects "that are of the utmost importance to society at large" (Rogers, 2013). This overlap is not unimportant as we often use political cues to make sense of complex scientific information (Funtowicz and Ravetz, 1993). Science is undoubtedly a part of public life in a democracy where citizens make decisions through voting choices and scientists, immersed in interdisciplinary research with high ELSI, have to increasingly address societal concerns. Yet, scientists' training does not appear to have kept pace with the development of interdisciplinary sciences.

3. Scientists lack formal training in public communication

While scientists are trained to be rational thinkers who emphasize knowledge acquisition and empirical evidence, they are usually not trained in skills required to be effective communicators. Most notably, communications and other social science courses are not typically part of formal course requirements for graduate degrees in the physical and life sciences (Brownell et al., 2013; The Kavli Foundation, 2012). A quick examination of course requirements at leading graduate programs in STEM fields reveals very few with requirements in areas of public communication or social sciences, more broadly.

Part of the persistence of the deficit model among scientists, we argue, can be attributed to this lack of formal training and understanding of communication and social science practices. In the simplest sense, scientists are not required to learn about communication practices as part of their scientific training, nor are they introduced to the established literature on opinion formation about scientific issues. The result is an overall lack of awareness about the processes by which citizens arrive at opinions and how to communicate effectively with such audiences. Given the lack of formal training in these areas, it is not surprising that scientists would follow the admittedly intuitive deficit model.

On the surface, it is not particularly startling that physical and life sciences graduate degree programs do not carry a requirement for communications or any other social science research courses. In fact, one might reasonably ask why a biology or chemistry program should require its students to take courses in communications. It hardly seems necessary when stacked against the other degree requirements. Nevertheless, there are benefits to the inclusion of such requirements, which are likely to only become more important over time. First, there is growing evidence that scientific communication via forms of social media can positively impact the careers of scientists. Media coverage of journal publications, for example, has been linked to increased citation numbers (Kiernan, 2003), and the number of Twitter mentions is correlated with higher *h*-index scores, a measure of research productivity (Liang et al., 2014).

Second, there is a growing expectation that scholars and researchers engage with public audiences in meaningful ways about their work. Most notably, Ralph Cicerone, the President of the National Academy of Sciences, has been especially vocal about the need for effective communication strategies to counter lagging public enthusiasm and comfort with science (Chemical & Engineering News, 2005). As part of his vision for communication, Cicerone has called directly on scientists to do a better job of engaging and communicating with public audiences (Cicerone, 2006). Academics and members of industry have echoed these calls, urging scientists to take advantage of recent developments in social media as means to connect with and educate public audiences (Van Eperen and Marincola, 2011). With little doubt, failing to provide the necessary tools and understanding of science communication makes

achieving these objectives a more difficult task. Exposure to formal communication courses as part of a graduate level curriculum can benefit scientists by expanding their understanding of how citizens form opinions about complex, and often controversial, science topics.

Filling the knowledge deficit of public audiences has tended to be a one-size-fits-all solution to the issue of public support for science. Although empirical evidence, in many cases, refutes the knowledge deficit model, a plethora of organizations and policies have been initiated as a result of Miller's work on science literacy. Organizations and policies rooted in the knowledge deficit conception of science literacy may increase outreach, but the efficacy of these efforts is compromised because those underlying assumptions usually do not hold true. More recently, however, programs have started to require communications courses as part of their majors. For instance, an M.S. degree in marine science at Stony Brook University requires students to take at least one course in science communication, as well as four credits of seminar courses with a heavy emphasis on student presentations (Stony Brook University, 2012; The Kavli Foundation, 2012). As the push for more formal communications and social science training for scientists continues, it should increase exposure to the diversity of research concerning the processes by which public audiences form opinions about science topics.

But will communications and social science research requirements lead to an elimination of the deficit model? Ironically, a push for social science course requirements in the hard sciences is itself a form of deficit model thinking as it is based on an expectation that mere exposure to social science research will lead STEM scientists to value the role of such work and, more importantly, incorporate its findings into their own public communication efforts. Yet, our data suggest that such course requirements will result in less adherence to the deficit model. Based on data from a survey of full-time, tenure-track, and tenured scientists at a large, R1 university in the United States,[1] we assessed what makes a scientist likely to adhere to the deficit model, despite the vast amounts of research against its efficacy in explaining how public attitudes are formed. Through regression modeling,[2] we found a correlation between scientists' attitudes toward social sciences and adherence to the deficit model. Specifically, we found that those with more positive attitudes toward social science as a discipline are less likely to support the deficit model of scientific opinion formation, at least for the issue of nanotechnology (Table 1). This represents the first empirical look at the impact of social science attitudes on deficit model thinking among scientists. The finding that scientists with more positive attitudes toward social sciences are more likely to de-emphasize the importance of knowledge in public attitude formation is in line with Weber and Word's (2001) argument that adherence to the deficit model is a product of underestimating how complex the decision-making process is for publics as they form attitudes toward science topics.

Scientists' acceptance of a hierarchy of the sciences, with "softer" sciences at the bottom, is well documented. As described by an editor of *Nature*, "it is the conventional wisdom in the biological and physical sciences, and within research agencies, that the social sciences are, well, 'soft,' and lacking in methodological rigor" ("In praise of soft science," 2005). There is plenty of anecdotal evidence of this conventional wisdom ("In praise of soft science," 2005: 1003; see Cole, 1983, for a comprehensive overview of the history of the hierarchy and empirical investigation into the legitimacy of the stratification). These results contribute to detailing the effects of acceptance of that hierarchy and attitudes associated with it.

Of course, since this analysis focused on only one controversial science issue, we are cautious with the interpretation of these results. Nevertheless, the relationship between scientists' attitudes toward social sciences and adherence to the deficit model presents both challenges and opportunities. On the one hand, some scientists may simply be unwilling to accept the findings of the so-called "soft sciences" when evaluating their own communication efforts. This overall negative outlook may mean that no amount of coursework or background in the area will shift their thinking about how publics form attitudes toward science. On the other hand, cultivating a more positive perception of the social sciences appears to be capable of shifting the prevailing thinking on the

Table 1. Predictors of moving away from the knowledge deficit model when it comes to how the public forms attitudes toward nanotechnology.

	Model 1	Model 2	Model 3
	β	*B*	*B*
Individual characteristics			
Gender (male = 1)	−.02	−.02	−.01
Age + years since PhD	−.08	−.08	−.09
Biological sciences	−.16**	−.17**	−.19**
Social sciences	.03	.02	−.02
Incremental R^2 (%)	*4.00**		
Value predispositions			
Religiosity		−.13*	−.13*
Political ideology		.03	.06
Incremental R^2 (%)		*1.40*	
Attitudes			
Attitude toward social sciences			.13*
Incremental R^2 (%)			*1.40**
Total R^2 (%)			*6.90*

Cell entries are final standardized regression coefficients for Blocks 1 through 3.
*$p \leq 0.10$, **$p \leq 0.05$.

topic. In other words, addressing this bias may lead to more positive attitudes toward the social sciences among scientists, which may in turn lead to more scientists moving away from the deficit model and move to more effective public outreach practices.

4. Most scientists view the public as a variety of "others"

Outside of views toward social sciences, the extent to which scientists view a knowledge deficit in non-scientific audiences is inextricably connected to their perception of who "the public" is. Many scientists who see themselves as rational citizens and decision makers see a problematic ignorance in public audiences and have clear ideas about *who* the public is, which often leads them to adopt a deficit mindset (Besley and Nisbet, 2013). For example, in a qualitative assessment of discourse surrounding genetically modified (GM) foods in the United Kingdom, researchers analyzed the use of the word "public" by scientists and observed that its use "suggest[s] its conception by most of our GM scientists as a homogeneous body" (Cook et al., 2004: 437). By repeatedly assuming and referencing public ignorance, the GM scientists tended to accept a deficit model mindset when thinking about how this perceived public feels about science. Additionally, according to a survey of science communication scholars, bench scientists and engineers are the least frequently trained in science communication and are the most likely group of scientists "to hold a deficit model perspective, the least likely to think the public have meaningful opinions, and the most likely to be out of touch with the public" (Besley and Tanner, 2011: 19). It is clear from such research that some scientists tend to see public audiences as an ignorant, homogenous group, and that such perceptions are associated with a deficit model approach.

We wanted to explore scientists' understanding of the public further, analyzing[3] university scientists' responses to the question, "What comes to mind when you hear the words, 'the public?'" In analyzing these data,[4] we were interested in answering several questions. Were scientists still viewing the public homogeneously? How did scientists view themselves in relation to the public?

Were there any indications that scientists were moving past a deficit model approach? Indeed, scientists' responses provided as much insight about how they perceive themselves as they did about their perceptions of the public.

As we coded these data several themes emerged, allowing us to classify scientists into different profiles. For clarity, we developed five profiles of participant scientists that shared similar characteristics in their thinking about the public. These categories are not mutually exclusive; some participants may fall within several categories.

Most of the responses (accounting for 75% of the codes) indicate that scientists conceptualize the public as an "other," a finding consistent with previous research on this subject (Blok et al., 2008; Cook et al., 2004; Kurath and Gisler, 2009). The public as the "other," however, is not a homogenous concept and there is much nuance to the groupings. Some believe the public to be a neutral other, while others are more definitive in describing the public as a non-scientific and neutral other. Some perceive the public as non-scientific and view this as a negative attribute, and still others perceive them as non-scientific but see this as positive. Scientists who do not think of the public as an "other" either identify as part of the public themselves or reject the term completely.

The public as neutral other

Approximately 22% of the coded responses conceptualized the public as a neutral other. These comments outlined the public as being comprised of many different kinds of people, but the nature of the responses suggested that the respondent was distinct from this group. Responses in this category contained no positive or negative judgments or feelings about the public, with comments often linking the idea of the public to participation in social life and activities, such as voting, consuming media, or interacting with the government. These comments tended to define the public as "average people" or "a very diverse and large bunch of people." Participants who made comments fitting into this category do not necessarily think that the public is ignorant and in need of education, as those who are inclined to adhere to a deficit model mentality tend to do, but they view themselves as distinct from other members of the public.

The public as neutral non-scientific other

One in five of the coded comments classified the public as other people who are "not scientific" and "outside academia and research," with one participant simply stating that the public is a "non-scientific audience." As with the previous category, this classification contained no positive or negative judgments or feelings about the public one way or another. For these scientists, the defining characteristic of the public was its placement outside the academy, that is, "individuals who live and work outside the university environment." These scientists have decided that the public is not only distinct from them, but that the public is decidedly unscientific, which may have implications for how these experts interact with such audiences.

The public as negative non-scientific other

A total of 18% of the coded comments classified the public as a negative non-scientific other. As with the previous grouping, comments fitting into this category depict the public as a group of others who are not scientific and are outside academia. However, comments within this classification expressed negative judgments and feelings toward the public. The negativity attached to these comments serves to build a hierarchy, one which places scientists in a superior position. Scientists who hold this opinion of the public may view and use intelligence and information as a figurative weapon, which can be used to ensure superiority, as is implied in the following response:

"Well-meaning people who think that they are informed, but are not really all that informed on matters of science and philosophy." Other comments falling into this group suggest that the public was narrow-minded, only caring about subjects directly related to them. Some respondents were particularly vocal in this area, arguing that the public is "[a] broad spectrum of individuals with diverse interests, expertise and experience, generally rather unaware, indifferent or sometimes recalcitrant to the importance of science in society." Emotions associated with these responses include hostility, frustration, and arrogance, exemplified by the words of one respondent who argued that "[m]ost people are idiots." Scientists who think in this manner would be expected to adhere very strongly to the deficit model, and it would not be particularly surprising if they were ill-informed about or unwilling to consider social science research about effective science communication.

The public as positive non-scientific other

A total of 15% of all comments fell into the category of positive non-scientific other. Responses in this category conceive of the public as a group of non-scientific individuals who reside outside of academia. A key distinction from the previous group, however, is that these comments do not lament this idea of the public. Rather, comments within this category expressed positive judgments toward the idea of the public and viewed the perspective of public outsiders as beneficial for science. Scientists who view the public as a positive non-scientific outsider typically value the contributions that an outsider perspective can add to science. Some participants may view the public as doing the best they can with the resources they have. They may also see that the public is paying for their research in some way and that it is a privilege to do research for them. One participant said the public includes "[p]eople, citizens, our bosses, the consumers, and beneficiaries of our work." Emotions that may be associated with these responses include optimism, enthusiasm, and hope, as evidenced in this response from one respondent: "eager to learn and know more." Such scientists might be more willing to turn to social science research about science communication, as they already hold positive attitudes toward public audiences.

The public as me

In contrast to each of the categories noted above, 12% of all comments failed to articulate that the public was in some way an outsider. In other words, some scientists internalize the idea of the public and identify themselves as part of the public. Scientists who made comments fitting this category think that the public is comprised of many different kinds of individuals who together make up a general public. Comments in this area did not make judgments or present valenced feelings about the public. One respondent described the public as "the sum of us," while another identified the public as "myself, my neighbors, the people in my community." Although these participants may not have explicitly made positive judgments of the public, the fact that they consider themselves a part of this collective suggests they see similarities with people who may be very different from them professionally. This suggests these scientists have more positive attitudes toward the public and consequently toward public communication of science.

The term "public" should no longer exist

The last group, which constituted 13% of all responses, believed the term "public" was outdated, not useful, and in some instances, patronizing or harmful. In these cases, scientists believed that the term was too general to provide real meaning, as seen in this response:

> The public is too generic of a term to be meaningful without more context. My outreach work reaches many different versions of "the public," so it is a moving target for me that I have to think about before each presentation or article, etc.

Others believed that the term has intrinsic negative judgments attached to it and that it promotes a hierarchy, with scientists at the top and laypeople at the bottom, as seen in this participant's response: "I do not like the term because to me it implies that the scientists are in a higher class — we are all 'the public'." Emotions that may be associated with these responses include indignance for others, sensitivity, and camaraderie. These scientists seem to view members of the public as equal to themselves and appear to realize that a one-size-fits-all approach, such as the knowledge deficit model, is often ineffective.

Implications of scientists' views of "the public"

These results have several important implications for our understanding of the deficit model. First, half of the participants tend to see the public as non-scientific. An additional 25% indicate that they view the public as an "other" entity that they are not a part of. These viewpoints separate scientists from other members of the public, creating an "us–them" dichotomy. Such thinking might further contribute to unequal power hierarchies in which scientists view themselves as separate and somehow above other members of society. An implication of this, of course, is that it might limit or prohibit meaningful engagement and communication between scientists and lay audiences. This may also indicate that scientists do not see nonscientists as part of the scientific dialogue or debate, despite the increasingly public and politicized nature of science today. For these scientists, simply allowing those outside academia into the realm of science might be the first step in moving beyond a deficit model approach.

Second, 18% of responses incorporated negative judgments of the public, which has implications for public engagement. If scientists perceive that the public is intrinsically ignorant, unintelligent, and lesser than themselves, it reasonably follows that they will adhere to a deficit model means of thinking, especially when there is public backlash to research or funding allocations. Only by filling this knowledge void and ridding people of their ignorance will the public be able to see the world in the same way as scientists. These scientists seem to believe that until the public has the "necessary" information, they are not a part of and should not be involved in science. Indeed, this line of thinking has been suggested in previous research. For instance, Besley and Tanner (2011) and Petersen et al. (2009) found that many scientists prefer one-way communication with the public that is rooted in the deficit model approach. Scientists operating under this mindset may be less willing to do meaningful outreach, connect with public audiences in ways that are understandable, or think about the public's role in the scientific process. A deficit model view is one of the significant predictors of scientists' participation in public outreach (Besley et al., 2012). Outreach driven by the view that the public's lack of knowledge is harmful likely has limited efficacy, and marginalizes audiences' contributions to engagement efforts. Additionally, analysis of scientists' perceptions of the GM food debate shows that though they nominally encouraged public participation in the debate, scientists' rhetorical practices discouraged and undermined public engagement (Cook et al., 2004). Unfortunately, even a small group of scientists who hold negative beliefs about the public can have damaging effects to science as a larger cultural institution.

Third, encouragingly, some scientists are expressing views of the public that seems divorced from the deficit model approach. These are participants who viewed the public positively (15%) and tended to have enthusiastic feelings about their place in science. These individuals may be

more willing to engage with the public in new and innovative ways, since they already hold positive opinions about the public. Another 13% of scientists' responses rejected the term "public" altogether, preferring instead to acknowledge the diversity of people and thereby eradicating the hierarchy between scientists and others. Because these scientists recognize the harm in assuming a monolithic, lower-class public, they may be particularly willing to use non-deficit-based approaches in connecting with these audiences.[5] In fact, many may already be doing so in their own work.

5. The deficit model works well for policy design

A final major reason that the deficit model persists likely has to do with a desire, particularly among scientists and politicians, for policy designs that can be easily implemented. Policy making can, of course, be a tricky business. In the United States, where most of our data has been collected, the process is typically slow-moving (Lindblom, 1959) and fraught with political gridlock as politicians, interest groups, and a host of other competing actors push to maximize the personal utility of a given policy (Renn, 1992).

From a policy making perspective, the allure of the deficit model approach lies in its simplicity. With its narrow focus on public knowledge levels, the deficit model approach has the benefit of identifying a specific source for the lagging public support for science. It pinpoints public ignorance as the problem and proposes a single and straightforward solution, that is, eliminate ignorance through education. This approach also has the added benefit of working within the confines of established infrastructure, the education system.

While it would be naïve to suggest that curriculum reform is a simple process, an approach to the lagging levels of public support for science that focuses on education enjoys at least one key advantage; it promises to be a largely bipartisan effort, at least relative to other approaches that might target values or employ persuasive messaging. In recent years, Democrats and Republicans have been at odds over a number of science issues, with many of these disagreements revolving around the use of federal funding for scientific research projects. Most notably, Representatives Lamar Smith (R-Texas) and Eddie Bernice Johnson (D-Texas) took to the media in 2013 to debate the merits of the High Quality Research Act, a proposal drafted by Smith that sought to

> require the director of the NSF to certify in writing that every grant handed out by the federal agency is for work that is "the finest quality, is ground-breaking, and answers questions or solves problems that are of utmost importance to society at large." (McAuliff and Grim, 2013)

In an era where science is becoming increasingly contentious politically, curriculum reform that is designed to produce a more educated citizenry represents an area of common ground for virtually all actors in the policy making process. While disagreements over the specifics of how to achieve this goal are inevitable (e.g. debates over teaching evolution), Republicans and Democrats, the rich and the poor, scientists and lay audiences all understand the need for a scientifically literate and informed citizenry. And, even the harshest critics of science seem to realize that future generations of scientists and engineers are needed to maintain our current way of life.

On the other hand, a more nuanced model of public science attitudes necessarily moves beyond education and information levels. Trust in scientific institutions, deference to scientific authority, and values, including religiosity and political ideology, represent murkier waters for building policy. These factors cannot be targeted through simple curriculum reform or exposure to new information. Rather, they are intertwined and highly open to interpretation. Any approach to policy making that targets the factors listed above ventures into more uncertain terrain and promises a more difficult battle for achieving reform.

6. Moving beyond the deficit model

We have presented four lines of reasoning for the persistence of the knowledge deficit model among scientists as they communicate with the public for the purpose of increasing scientific understanding and/or support: the juxtaposition between how scientists are trained and how the public processes information, institutional structures that continue to support the deficit model, scientists' conception of "the public," and the allure of the deficit model for policy making. At the same time, we have uncovered some encouraging evidence that indicates some scientists may be moving beyond a knowledge deficit mindset and understanding other goals of science communication. Science is more socially embedded than ever and some scientists appear to be recognizing this. Scientists who view public audiences positively may be more receptive to understanding the public's role within science itself and reacting appropriately. Some of these scientists who are ready to move beyond a broad, patronizing view of the public may already be working to engage the public and may be more receptive to new and innovative methods of engagement. And, we speculate that scientists who understand that they, too, are part of the public may be more understanding of how people view science and of the fact that they are continually making value judgments in their own work. These scientists, therefore, are likely to be ready to explore approaches that go beyond the idea of a public as information deficient.

Additionally, we have some suggestions for how we can continue moving science communication past the deficit model approach. This brief list is by no means comprehensive, nor is it intended to prescribe social science solutions to science's image problem. Rather, its purpose is to highlight and offer potential directions forward for the present and the future scientists and science communicators whose goals include increasing public understanding of and/or support for science.

First, we can continue the training of science communicators. Universities such as Boston University, the University of California–Santa Cruz, and the University of Wisconsin–Madison have strong programs in science communication and journalism. These programs are producing science communication specialists who can bring scientific information to different audiences in ways that are understandable, engaging, and supported by empirical social science research. Although the media landscape is changing and there are fewer journalism positions each year (Pew Research Center, 2014a), there is still a great need for well-trained science communicators.

Second, we can continue training scientists in positive communication methods grounded in social science research. Scientists rarely encounter mandatory formal communication training as part of their education (Brownell et al., 2013), although we have noted at least one exception. However, outside of course and degree requirements, there are additional educational opportunities for scientists who wish to improve their communication skills, such as those offered through the Alan Alda Center for Communicating Science and the American Association for the Advancement of Science's (AAAS) Center for Public Engagement with Science and Technology. The NSF is also promoting science communication training through programs like the Integrative Graduate Education and Research Traineeship and the NSF Research Traineeship, further showing a top-down commitment to science communication. Scientists must self-select into these opportunities, and a short workshop may not be able to cover in-depth the scholarship about how people process information and form opinions. Nevertheless, these projects represent progress in combating deficit model thinking. These workshops and programs should be encouraged to reach more scientists; science communication and public engagement should be part of formal training for scientists in graduate programs.

Finally, we can use approaches that engage community members around scientific issues in which they are inherently interested when such approaches are appropriate. Community-based research (CBR) focuses on a topic that is of interest to a community, works to involve both community participants and researchers fairly, and tries to produce results that can solve community

problems and contribute to positive social change (Strand et al., 2003). Projects can involve nonscientists in many different capacities. Citizen science projects ask members of the public or communities to be involved in different parts of the research process. Examples of citizen science projects include classifying data that have already been collected, such as the Galaxy Zoo project that asks web users to classify pictures of galaxies (http://www.galaxyzoo.org), or collecting data, such as the Seabird Ecological Assessment Network (SEANET) project about threats to marine birds (http://vet.tufts.edu/seanet/). While some may argue that data collected by nonscientists are unreliable due to high levels of variability, researchers invested in citizen science have worked to correct variability in these data collections (e.g. Moyer-Horner et al., 2012). Projects can also use the skills of nonscientists in greater capacities, such as determining exposure to pesticides, restoring a natural area, or solving a health problem Holkup et al. (2004), McCauley et al. (2001), and Serrat-Capdevila et al. (2009). Using a community-based approach to science problems, working with communities to answer their scientific questions, or using citizen science solutions are all ways to involve members of the public in the scientific process, which can increase their understanding and engagement with science. CBR is not an appropriate approach for all topics but should be considered when possible.

This essay focuses on a particular conception of science communication: understanding why the knowledge deficit model is appealing to scientists and science communicators whose communication goals include increasing understanding of and support for science. Burns et al. (2003) identified other motivations for engaging in science communication, such as awareness, enjoyment, and interest, and there are arguably other purposes of science communication, as well, such as political persuasion, education, and civic duty. Additionally, there are conceptions of science communication that are rooted in different normative assumptions than those we have assumed in this essay. For example, many who view the purpose of science communication as a vehicle to increase understanding of and support for science hold a stakeholder view of scientists and science organizations as participants in public communication. Acceptance of this normative assumption is implicit in our argument, in large part because we are assessing the deficit model from the perspective of scientists, who often approach science communication from a stakeholder perspective. However, we recognize that accepting this assumption is in many ways limiting, as it is not a universal perspective. A comprehensive normative reflection on the goals of science communication would serve scientists, science communicators, and science communication scholars well.

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Notes

1. Data were collected in the spring of 2013. Our sample included tenured and tenure-track research faculty in the social, biological, and physical sciences at a large, Midwestern research university (N = 254, response rate = 20.5%), with 36.9% of respondents in biological sciences, 34.8% in physical sciences, 28.3% in social studies/social sciences. For more information on data collection, see Simis (2013).
2. The seven independent variables included in the hierarchical regression are gender, discipline, age and years since PhD, religiosity, political ideology and, most important to this study, attitudes toward social sciences (an index composed of two variables that measure how rigorous the respondent thinks social

science is; $r = .37$, $p < .01$). The dependent variable is an index measuring scientists' perceptions of the importance of the knowledge deficit model in the formation of public attitudes (an index composed of three variables that measure how important respondents think the role of knowledge is in attitude formation; Cronbach's $\alpha = .70$ and mean inter-item correlation = .43). Because of the small sample size and the exploratory nature of this study, the alpha level for this analysis is .10.

3. These data were collected in the spring of 2013, in the same survey as those used in the previous analysis presented in this article. Again, our sample included tenured and tenure-track research faculty in the social, biological, and physical sciences at a large, Midwestern research university. For more information on data collection, see Simis (2013).
4. Two coders analyzed these data by inductively producing comprehensive codes and then coding the entire dataset. The inter-coder reliability statistic of Krippendorf's alpha (which was conducted on 30% of the data) is .848 (95% confidence interval (CI) = .747, .932). A total of 392 codes were ascribed to the 166 responses.
5. We attempted to verify these claims by examining correlations between our different profile types and reported attitudes toward the deficit model. While many of the findings trended in the directions we note above, statistical significance was not to be achieved. This is likely a product of our small sample size, which was further reduced as several respondents opted out of responding to the open-ended item asking them to define the public.

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