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Communicating Who Knows What in Sustainability Science: Investigating the Role of Epistemology in Science Communication and Engagement

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COMMUNICATING WHO KNOWS WHAT IN SUSTAINABILITY SCIENCE: INVESTIGATING THE ROLE OF EPISTEMOLOGY IN SCIENCE COMMUNICATION AND ENGAGEMENT

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Dr. Laura Lindenfeld, Director, Alan Alda Center for Communicating Science 3/31/2016

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COMMUNICATING WHO KNOWS WHAT IN SUSTAINABILITY SCIENCE:

INVESTIGATING THE ROLE OF EPISTEMOLOGY IN SCIENCE

COMMUNICATION AND ENGAGEMENT

By Brianne M. Suldovsky

Dissertation Advisor: Dr. Laura Lindenfeld

An Abstract of the Dissertation Presented
in Partial Fulfillment of the Requirement for the
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The complex socio-ecological problems we face today often require that researchers collaborate with individuals and organizations outside of their own disciplines and, oftentimes, outside of academia entirely. This sustainability science model encourages university researchers to engage in participatory models of engagement, where nonscientific publics and scientists working outside of academe are invited to co-produce knowledge and, through collaboration, arrive at solutions for sustainability. Despite the popularity of participatory models of engagement in sustainability science, very little research has examined sustainability science researchers' perceptions of epistemic authority in conjunction with their engagement behavior. This kind of work is important given that the epistemic privileging of science can function as a significant barrier to the creation of meaningful solutions, particularly when it comes to persuading diverse groups of people to buy-in to one particular solution over another in complex sustainability-related contexts.

I combine science communication theory with the concepts of epistemic authority and expertise to explore stakeholder engagement within a large sustainability science research effort. In chapter one, I explore the potential underlying factors, including epistemic assumptions, that drive model use, specifically addressing the continued use of the diffusion model (i.e. public deficit) in science communication research and practice. In chapter two, I qualitatively explore the extent to which sustainability science researchers afford science epistemic authority and assess their use of different models of science communication within their stakeholder engagement efforts. The results of chapter two challenge the assumption that sustainability science creates an egalitarian epistemic environment and the presumed connection between sustainability science and participatory models of engagement. In chapter three, I quantitatively examine the relationship between NEST researchers' perceptions of stakeholder expertise and their science communication behavior. Results of this chapter three indicate a positive relationship between how sustainability science researchers perceive the expertise level of their stakeholder partners and the manner in which they engage those partners. Taken together, this work adds to the growing body of literature in science communication that explores how different models of science communication emerge and demonstrates the value of studying the relationship between epistemic assumptions and science communication practice.

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INTRODUCTION

Communicating science is of growing interest for communication scholars and practitioners. This interest is driven by the often-cited gap between the scientific community and various publics (Bensaude-Vincent, 2001; Haines, Kuruvilla, & Borchert, 2004; Joseph et al., 2013; Sismondo, 2010; Wandersman, 2003) and the presumption that “improved communication among the expert community, policy makers, media professionals, and the general public” (Dudo, 2013, p.477) will aid us in effectively addressing the most pressing social, ecological, and economic issues that impact our everyday lives. Science communication research is multifaceted and complex, and tackles a broad range of topics including climate change (Kakonge, 2013), public health (Y. Bar-Tal, Stasiuk, & Maksymiuk, 2013), ecosystem management (Castillo, 2000), nuclear energy (Fahlquist & Roeser, 2015), and forestry (Zimmerman, Akerelrea, Smith, & O’Keefe, 2006). Science communicators engage different publics, work in arenas that range in scale from local to global, and utilize a variety of communication techniques. This variability precludes us from employing a one-size-fits-all approach to science communication practice (Trench, 2008). The communication technique that is effective when communicating with policy makers about climate change, for example, will likely not be the same technique that is effective when communicating with homeowners about the risk of arsenic in their drinking water.

There are three communication models in science communication: diffusion (i.e. deficit), dialogue and participation (i.e. knowledge co-production) (Bucchi, 2008). Diffusion is a one-way model of communication, where scientific information is transmitted from experts to lay audiences in an effort to inform or persuade those audiences. The diffusion model has been heavily criticized for being overly simplistic (Bucchi, 2008; Hansen, Holm, Frewer, Robinson, & Sandøe, 2003; Sturgis & Allum, 2004), largely ineffective (Holland et al., 2007; Nisbet & Mooney, 2007), and unfairly characterizing those opposed to scientific activities or endeavors as necessarily deficient or ignorant (Bucchi, 2008; Priest, 2001). In light of these critiques, it remains widely utilized in both research (Tøsse, 2013) and practice (Davies, 2008).

The dialogue model is a two-way model of communication, which serves as an effort to remedy the shortcomings of the diffusion model. Rather than a one-way transmission of information from experts to lay audiences, the dialogue model promotes two-way communication between scientific experts and various publics in an effort to create shared understanding between communicators, develop trust, and strengthen social relationships. The dialogue model has been criticized for sharing the diffusion model's "obsession with demarcating lay knowledge and the only knowledge of any value: that which warrants the term 'scientific'" (Bucchi, 2008, p. 68). Even when nonscientific expertise is considered, it is often judged against a scientific rubric, particularly in practice (Holm, 2003).

As a result, many science communication scholars call for an additional shift beyond the dialogue model in an effort to be more inclusive of alternative methods of science communication that embrace nonscientific perspectives "as essential for the production of knowledge itself" (Bucchi, 2008, p. 68). The shift beyond dialogue necessitates a greater role for nonscientific audiences in the process of knowledge production. Often referred to as knowledge co-production, the science communication model of participation is a multi-directional communication model that encourages science communicators to be more inclusive of nonscientific perspectives in the process of knowledge production.

Participatory models of communication and engagement are particularly popular within sustainability science, where incorporating diverse needs, perspectives, and knowledges is necessary for effective problem solving (Cash et al., 2003). The increasingly complex socio-ecological problems we face today often require that researchers collaborate with individuals and organizations outside of their own disciplines and, oftentimes, outside of academia entirely. Within this postnormal (Funtowicz & Ravetz, 2003) model of scientific research, university researchers are regularly encouraged to engage in participatory models of engagement, where nonscientific publics are invited to produce knowledge, negotiate meanings, and co-create solutions. Within this type of engagement, science is no longer viewed as the epitome of contemporary knowledge production, and is instead integrated with other knowledge types (e.g. traditional ecological knowledge).

All three science communication models embed particular epistemic assumptions and public expertise within them (Hetland, 2014). The diffusion model (which necessitates little or no interaction between communicators) assumes the least amount of public expertise, in that the model assumes the public lacks the knowledge they need and communication serves as a remedy for this information deficit. The dialogue model (which necessitates a moderate amount of interaction between communicators) assumes a moderate amount of public expertise, in that the model takes the public to be competent in providing substantive feedback and engaging with scientific experts. The participation model (which necessitates continuous interaction between communicators) assumes the highest level of public expertise, in that public input is understood as central to knowledge production itself.

Work that links science communication models with epistemic assumptions and perceptions of public expertise exist almost exclusively within the theoretical development of these models. Very little work has examined the relationship between epistemic assumptions and science communication practice, particularly within a sustainability science context. In addition, despite the popularity of participatory models of engagement in sustainability science, very little research has examined sustainability science researchers' perceptions of epistemic authority in conjunction with their engagement behavior. This kind of work is important given that the epistemic privileging of science can function as a significant barrier to the creation of meaningful solutions, particularly when it comes to persuading diverse groups of people to buy-in to one particular solution over another in complex sustainability-related contexts.

I address this gap in this dissertation by combining science communication theory with the concepts of epistemic authority and expertise to explore stakeholder engagement within a large sustainability science research effort. This work adds to the growing body of literature in science communication that explores how different models of science communication emerge and how they ought to emerge (Bucchi, 2008). In addition, this work exhibits the utility of a science communication framework in studying and systematizing stakeholder engagement in sustainability science. Finally, this work demonstrates the value of studying the relationship between epistemic assumptions and science communication practice.

The work within this dissertation sits within the context of three guiding questions regarding science communication, epistemology, and sustainability science, including: How and why do different models of science communication emerge? What is the relationship between epistemic assumptions and science communication practice? How might science communication research inform sustainability science? I address these three questions to a greater or lesser extent in each of the three chapters outlined below. I include a more detailed discussion of the implications of this work as it relates to these questions within the conclusion of this dissertation.

Study context

The New England Sustainability Consortium's Safe Beaches and Shellfish Project is the context for this work. This three-year research project brings together researchers from University of New Hampshire, University of Maine, Keene State College, University of Southern Maine, College of the Atlantic, University of New England, Great Bay Community College, and Plymouth State University. NEST brings social and biophysical researchers across these institutions together in order to strengthen the scientific basis for decision-making surrounding pathogenic bacterial pollution along the Maine and New Hampshire Coast, including improving the process of closing of shellfish beds and posting of beach advisories. Current coastal water quality assessment programs and subsequent decision-making procedures in both states are poor indicators of actual risk.

As a result, public health is not sufficiently protected and shellfish beds are often closed far longer than they need to be. These dynamics create a significant economic loss for shell fishermen and the state of Maine. NEST aims to develop a better understanding of how environmental conditions (e.g. rainfall events, topography, ocean temperature, water runoff, etc.) impact pathogenic dynamics and risk level for humans: "There is widespread agreement among resource managers and scientists in both states that current beach and shellfish management approaches are flawed; sustainability science research methods offer a means to address these flaws" (New Hampshire EPSCoR, 2016). NEST is funded by the National Science Foundation's Experimental Program to Stimulate Competitive Research (EPSCoR). EPSCoR aims to diversify participation and organizations in scientific research and foster effective engagement with the public. The interdisciplinarity, breadth of engagement activities, diversity of stakeholder partners, and commitment to advancing the use of science in decision-making on NEST make the Safe Beaches and Shellfish Project an ideal context within which to study science communication dynamics.

Chapter overview

In this dissertation, I explore the relationship between epistemic assumptions and science communication practice in three phases. In chapter one, I explore the potential underlying factors, including epistemic assumptions, that drive model use, specifically addressing the continued use of the diffusion model (i.e. public deficit) in science communication research and practice. In chapter two, I qualitatively explore the extent to which NEST researchers afford science epistemic authority and assess their use of different models of science communication within their stakeholder engagement efforts. In chapter three, I quantitatively examine the statistical relationship between NEST researchers' perceptions of stakeholder expertise and their science communication behavior.

Chapter one

Despite mounting criticism, the deficit model (a central component of the diffusion model) remains an integral part of science communication research and practice. In this chapter, I advance three key factors that contribute to the idea of the public deficit in science communication: the purpose of science communication, how communication processes and outcomes are conceptualized, and how science and scientific knowledge are defined. Affording science absolute epistemic privilege, I argue, is the most compelling factor contributing to the continued use of the deficit model. In addition, I contend that the deficit model plays a necessary, though not sufficient, role in science communication research and practice. Opportunities for future research, which include the research conducted in chapters two and three, are presented.

Chapter two

The participatory model of stakeholder engagement is typically considered an ideal method of stakeholder collaboration within sustainability science. This model attempts to integrate alternative (or "nonscientific") perspectives into scientific research and problem solving processes. However, very little research has examined researchers' perceptions of epistemic authority in conjunction with their engagement behavior. This kind of work is important given that the epistemic privileging of science can function as a significant barrier to the creation of meaningful solutions, particularly when it comes to persuading diverse groups of people to buy-in to one particular solution over another in complex sustainability-related contexts. In this chapter, I use the concept of epistemic authority and science communication theory to qualitatively examine NEST researchers' perspectives on the epistemic authority of science and their stakeholder engagement practice. Results challenge the assumption that sustainability science creates an egalitarian epistemic environment. In addition, this work challenges the presumed connection between sustainability science and participatory models of engagement. Implications and directions for future research are discussed.

Chapter three

In this final chapter, I build off of the qualitative results presented in chapter two and quantitatively explore the relationship between researchers' perspectives on stakeholder expertise and their science communication behavior. The relationship between expertise and the three science communication models outlined above has been theoretically addressed in previous work (Hetland, 2014). However, very little work has quantitatively demonstrated the relationship between perceptions of expertise and actual science communication practice, particularly within sustainability science. I address this gap by quantifying NEST researchers' perceptions of stakeholder expertise and their science communication behavior and testing the correlational relationship between the two. The results of this study indicate a positive relationship between how NEST researchers perceive the expertise level of their stakeholder partners and the manner in which they engage those partners.

CHAPTER ONE

IN SCIENCE COMMUNICATION, WHY DOES THE IDEA OF THE PUBLIC DEFICIT ALWAYS RETURN? EXPLORING KEY INFLUENCES

Introduction

Science communication is “a complex and contentious topic that encompasses a spectrum of issues from the factual dissemination of scientific research to new models of public engagement whereby lay persons are encouraged to participate in science debates and policy” (Bubela et al., 2009, p. 514). Despite the broad spectrum of issues encompassed by science communication, there is one concept that has historically driven a vast majority of science communication: the public deficit, or deficit model. The deficit model has been heavily criticized for being overly simplistic (Hansen et al., 2003; Sturgis & Allum, 2004), largely ineffective (Holland et al., 2007; Nisbet & Mooney, 2007), and unfairly characterizing those opposed to scientific endeavors as necessarily deficient or ignorant (Priest, 2001). Despite these criticisms, it remains widely utilized (Besley & Tanner, 2011; Davies, 2008; Miller, 2010)

In this chapter, I review the persistence of the public deficit in science communication research and practice. The purpose of this chapter is not to over-generalize or erroneously simplify science communication scholarship or practitioner activities as these efforts cross geographic (Schiele, Claessens, & Shi, 2012), disciplinary (Donghon Cheng et al., 2008), and cultural (van Dijck, 2003) boundaries. The purpose of this article, rather, is to illuminate key factors that support the persistence of the public deficit to greater or lesser extents across these heterogeneous domains. To begin, I briefly summarize the concept of a public deficit and the different components of the deficit model. Then, I overview each factor and utilize existing science communication research and practice to elucidate their significance. Finally, I argue for the necessary, though not sufficient, role the public deficit plays in science communication and highlight key opportunities for future research.

The public deficit

The deficit model aims to remedy the fractured relationship between science and society. This relational fracture is demonstrated through a broad spectrum of issues including scientific literacy (National Science Foundation, 2014), public health (McMurray et al., 2004), declining scientific funding (Harris & Benincasa, 2014), and public policy (Mossman, Bignon, Corn, Seaton, & Gee, 1990). There are three distinct components of the deficit model: that of product, process, and remedy. The first component of the deficit model emphasizes the *products* of science (i.e. scientific knowledge) and claims that there is a problematic gap between non-specialists and "selected nuggets of high-quality [scientific] knowledge" (Gregory, 2011, p. 307). Whether it be individuals looking online for health-related information (Treise, Walsh-Childers, Weigold, & Friedman, 2003), or scientists seeking to provide information to inform public policy (Khanna, 2001), the goal within this context is to transfer scientific knowledge from one individual or group to another. This component of the deficit model centers on public understanding of scientific facts (i.e. scientific literacy), surrounding topics like evolution (Nisbet, 2005). The second component of the deficit model emphasizes science as a *process* and claims that public skepticism and negative attitudes toward modern science are due to "a lack of adequate knowledge *about* science" (Besley & Tanner, 2011, p. 243; emphasis added). In contrast to product, this component focuses on how to improve attitudes toward science as an activity (Winkleby & Ned, 2010) and legitimate the place of science in the modern world. The third component of the deficit model posits that the remedy for less-than-desirable public understanding of science (both product and process) is improved communication. That is, the deficit model "centers on an explanation of the relationship between science and society as one of communication" (Wright & Nerlich, 2006, p. 332). While the deficit model has been heavily criticized, it remains an integral component to science communication research and practice.

Why we persist

The failure of the deficit model to adequately represent the relationship between science and society (Engdahl & Lidskog, 2012) and to remedy the gaps that exist (Wilkinson, 2010) has been repeatedly demonstrated. In addition, there has been a large push to move beyond the deficit model toward more deliberative, participatory models of science communication (Palmer & Schibeci, 2014), where the public is encouraged to actively participate in scientific processes. Even so, the deficit model remains an integral component of science communication research and practice. In this section, I outline three key factors that foster and reinforce the idea of the public deficit, including the purpose of science communication, the conceptualization of communication processes and outcomes, and how science and scientific knowledge are defined.

Science communication's purpose

Concern regarding public understanding of science became mainstream in the mid-1980s following the publication of the Bodmer Report (Bennett & Jennings, 2011; Wilkinson, 2010). Since that time, initiatives to increase public understanding of science through the use of science communication have flourished on a global scale (Bucchi, 2008). Science communication practice has had a much longer history compared to its scholarly counterpart (Bucchi, 2008) and includes efforts like science centers and museums, public awareness programs, public policy outreach, and science journalism (Bruyas & Riccio, 2013). The general purpose of science communication practice is to improve the relationship between science and society and promote science within the public sphere through a variety of means, including improving scientific literacy (Utz, Rausch, Fruth, Thomas, & van Breukelen, 2007), connecting science and policy (American Association for the Advancement of Science, 2013), cultivating positive perceptions of science (Aurentz, Kerns, & Shibley, 2011), or disseminating scientific information to the public (Colson, 2011).

Similar to science communication practice, science communication research often carries with it an underlying responsibility to promote science within the public sphere or, at the very least, foster a better relationship between science and society. Surely, there is research that seeks only to examine popular perceptions of science (Ruiz-Mallén & Escalas, 2012) or study how science is portrayed in the public realm (Alcíbar, 2008). However, a large portion of science communication scholarship carries with it an underlying "responsibility to nurture and optimize the relationship between science and society" (Nan, 2008, p. vii).

Science communication's foundation and the very notion of "responsibility" assume that the relationship between science and society is not automatic and must be created, nurtured, and sustained through communication. Importantly, this communicative relationship between science and society is often (although certainly not always) conceived as unidirectional, where science stands to improve society but society does not stand to improve science. While this unidirectional relationship has been challenged within fields like science and technology studies (Jasanoff & Markle, 2001) and philosophy of science (Barker & Kitcher, 2013), it still lingers in some facets of science communication research and practice. Part and parcel with this conceptualization of the science–society relationship is a one-way model of communication from scientific sources to lay audiences or public deficit. So long as science communication research and practice is founded upon the desire to resolve a problematic gap through the use of (often) one-directional communication, the public deficit will have an integral role within that process.

<u>Communication</u>

As noted above, the deficit model rests on the assumption that the ideal relationship between science and society is one of communication (Wright & Nerlich, 2006). Given this communicative relationship, it is worthwhile to examine how communication as a process is conceptualized in science communication and explore how that conceptualization might support the concept of a public deficit. The practice of science communication has undergone a similar shift to science communication research: that of "deficit to dialogue" (Trench, 2008). Most notably, it has broadened its efforts to better foster dialogue between scientists and the public (Bruyas & Riccio, 2013) and has moved from focusing on scientific literacy to focusing on the role of science in society (Bauer, 2009). Even so, the deficit model is demonstrably present in current science communication practice (Trench, 2008).

For the bulk of science communication research, scholars have echoed practitioners and utilized a linear, diffusion model of communication (Bucchi, 2008) that typifies communication as information transfer. Diffusion is a fairly common communication model within and outside of science communication scholarship (Sheperd, St. John, & Striphas, 2006). According to Dearing (2006), a proponent of the diffusion model:

> To conceptualize communication as diffusion is quite efficient, for doing so is to focus on what really counts: the most important communications; the messages we interpret as both risky and rewarding; and the ideas that have real consequences, good and ill. For diffusion, whether concerned with purposive intent by some to spread an innovation to others, or whether focused on imitative behavior that constitutes a real change by thousands or millions of people, is the study of meaningful and consequential ideas, the ideas that catch on and that wash over whole social systems of people, organizations, communities, and populations ... Diffusion is a social process by which innovation is communicated over time among the members of a communication network or within a social sector. An innovation can be an idea, knowledge, a belief or social norm, a product or service, a technology or process, or even a culture, as long as it is perceived to be new. (p. 175)

That is, communication as diffusion defines communication as a process by which new ideas, knowledge, beliefs, social norms, products, services, technological advancements, and culture are communicated across a social group.

Within science communication, the diffusion model conceptualizes communication as a means of disseminating scientific information including ideas, knowledge, technologies, or processes. It is worthy to note that some science communication scholars explicitly employ diffusion theory "which describes how innovations spread through society" (Dumlao & Duke, 2003, p. 288). Diffusion uses the traditional, linear, one-way model of communication (Shannon and Weaver, 1949), wherein there is a sender, a receiver, and a message, all three of which exist separately from each other and can be broken down into individual units. Communication as diffusion assumes that the ultimate goal of communication is the *acquisition and utilization* of scientific information by non-scientific audiences. The diffusion framework can be seen in the following excerpts from science communication literature (emphases added):

> People today may take advantage of the accessibility of the Internet to **acquire information** about a much broader range of [health] topics than they previously would have investigated. (Treise et al., 2003, p. 330)
>
> Within the ecological scientific community, communication frequently has been recognized as a factor that plays an important role **in the utilization of research findings**. (Castillo, 2000, p. 49)
>
> A researcher's job is not over until the research findings have been peer reviewed and published, **have been disseminated to all those who can use the information** (including laypeople), and (where applicable) have led to the desired policy impact. (Khanna, 2001, p. 51)
>
> The goal [is] to **provide the public with the best information** available on teach topic from trusted organizations. (Lacroix, 2001, p. 285)

The widespread use of communication as diffusion does not mean that all science communication scholarship embraces diffusion, nor does it mean that this diffusionist conceptualization has not been previously challenged. Rather, it suggests that the diffusionist model is still very prevalent in research and practice and, therefore, still stands to influence the prevalence of the public deficit.

There are multiple suppositions embedded within communication as diffusion that relate to both science communication research and practice. First, diffusion understands communication to be a broad process "concerned with the transfer of knowledge from one subject or group of subjects to another" (Bucchi, 2008, p. 58). That is, the ultimate and solitary goal of communication within a diffusionist framework is the transfer of information from a sender to a receiver, and communication success is "defined as the achieved transfer of information from one party to another" (Bucchi, 2008, p. 66). Second, the diffusionist model views science communication as a linear, one-way process where the contexts of the communication sender (e.g. a scientist) and receiver (e.g. the public) "can be sharply separated, only the former influencing the latter" (Bucchi, 2008, p. 58). In other words, this model does not allow for the inclusion of communicator context or the existence of mutual influence between communicators. Third (and relatedly), the diffusionist model takes knowledge to be something that can be transferred "without significant alterations from one context to another, so that it is possible to take an idea or result from the scientific community and bring it to the general public" (Bucchi, 2008, p. 58). That is, it views knowledge as a fixed, context-independent phenomenon that ought to be taken from the scientific community and delivered, unchanged, to the public. Fourth, and finally, the diffusion model takes the public as a passive consumer of information "whose default ignorance and hostility to science can be counteracted by the appropriate injection of science communication" (Bucchi, 2008, p. 58). The default assumption of public ignorance rests, in part, on the idea that science is too complicated for the public to understand. The assumption of inherent public ignorance "underpins a widespread conception, if not an outright ideology, of the public communication of science" (Bucchi, 2008, p. 58).

Bucchi (2008) claims that this final tenet of science communication as diffusion is what we refer to as the deficit model and that the deficit model is part and parcel to our use of communication as diffusion. However, I argue that all four of these tenets mirror the propositions and assumptions central to the deficit model, including a focus on communication as a means for information transfer, communication as a linear, one-way process where senders (scientists) and receivers (lay audiences) can be sharply differentiated, an understanding of scientific knowledge as an objective, package-able product (see discussion below), and the assumption that improved communication will remedy less-than-desirable public understanding of, and attitudes toward, science. This is not to say that this particular understanding of communication causes the deficit model, or vice versa, but rather that both function to reinforce each other.

Defining science and scientific knowledge

In addition to science communications' purpose and characterization of communication, how scholars and practitioners understand science as an endeavor can have a significant impact on how they conceptualize and implement its communication. The scientific process is, by its very definition, inextricably linked to knowledge acquisition ("Science," 2014), meaning that we accept science as a method of discovering things about our world that would likely otherwise be left undiscovered. Conceptualizing the scientific process as a means to produce new knowledge necessitates a view of a public deficit in that science is providing society with information it does not yet have (Miller, 2010). Presumably, the scientific community is given the charge of acquiring said knowledge, differentiating them from non-scientific publics and supporting the idea that the public are inadequately informed about science topics (Besley & Nisbet, 2013). In addition, science is represented in popular culture as a product of individual “great men” producing scientific knowledge in isolation (Hook & Brake, 2010), and subsequently disseminating that knowledge to a less educated public.

Taken together, these dynamics create a linear, top-down (read deficit) model of knowledge dissemination. Wright and Nerlich (2006) highlight the link between how we understand the scientific process and our communication:

> [The] arguments structuring the deficit model tie in with concurrent assumptions about the nature of science itself. Namely, that science lies outside of society, inhabited by professional scientists with whom lines of communication need to be built. Although this belief has been challenged ... it remains a durable and popular concept inside and outside the sociology of science. (p. 333)

Put simply, so long as science is conceptualized as a process that takes place outside of society and provides us with new information, particularly information that can be utilized by non-scientific audiences, the public deficit will remain an essential component of science communication research and practice. This is not to imply that the definition of science is a given. What science is and ought to be is rigorously studied and debated, and there are entire academic fields (e.g. philosophy of science) dedicated to parsing out exactly what science is and how it functions in society (e.g. Bird, 2006).

How individuals outside of those highly specialized realms understand science, though, primarily comes from its representation in popular culture (Hook & Brake, 2010) and previous experience (Wilkinson, 2010). It seems unrealistic (and fairly unnecessary) for science communication scholars to critically evaluate their understanding of science at this time. However, it is important to consider the connection between how science as a process is understood and how its communication is conceptualized.

In addition to how science is conceptualized, how scientific knowledge is defined and positioned in relation to other knowledge sources has an equally important role to play in fostering a deficit model of science communication. Often, science is assumed to have epistemic authority or "a source on whom an individual may rely in her or his attempts to acquire knowledge on various topics" (Kruglanski et al., 2005, p. 351). This view is not only held by scientists and science communication professionals, but often by the public, especially in matters of public policy (O'Brien, 2013). Scholars who study epistemic authority maintain that knowledge acquisition is interpersonal in nature (D. Bar-Tal, Raviv, Raviv, & Brosh, 1991) and that the authority we afford various sources to produce and provide us with knowledge has a substantial impact on our decision-making processes and behavior (Kruglanski et al., 2005). People assign epistemic authority to different sources for different reasons, including seeing a source prove their knowledge (e.g. when a prediction pans out), seeking approval from a source (e.g. parents), the desire to see a source as authoritative (e.g. a religious leader), or the need to affirm one's own beliefs and views (Kruglanski et al., 2005). It is important to note that epistemic authority is context-specific, in that some sources exert authority in numerous life domains, like a therapist or priest, while others may exert influence only in specific contexts, like a mechanic or statistician (Kruglanski et al., 2005). Epistemic authority has been deliberated by philosophers in relation to a variety of topics (Zagzebski, 2012), and it has been studied within the context of political beliefs (D. Bar-Tal, Raviv, & Freund, 1994), collaborative science (Zagzebski, 2012), physician expertise (Y. Bar-Tal et al., 2013), and college professors (Blumberga, 2012; Raviv, Bar-Tal, Raviv, & Abin, 1993).

Affording a source epistemic authority is incredibly powerful, "so powerful, in fact, that it may override all else and exert a determinative influence on the individual's judgments and correspondent behavior" (Kruglanski et al., 2005, p. 352). The role of science as an epistemic authority drives the concept of a public deficit, in that it forces communication to function in a top-down, one-way structure where knowledge trickles down from an epistemic authority (scientists) to a knowledge-deficient audience. That is, when science is selected or assumed as the epistemic authority for a domain (or numerous domains), the deficit model is sure to follow.

In addition to explaining why the deficit model persists in science communication, understanding the role of epistemic authority in decision-making may shed light on why the deficit model is effective in some science communication contexts and ineffective in others. That is, affording science epistemic authority is not inherently problematic, but it can become problematic for science communication when we assume that those we are communicating with afford science the same superior epistemic position. The job of the science communicator from an epistemic perspective, then, is to establish or maintain the epistemic authority of science and to leverage that authority in an effort to transfer information, improve attitudes, or alter behavior. Within this framework, the deficit model becomes ineffective if those who we are communicating with do not assume science to have epistemic authority regarding the topic or phenomenon at hand: that is, the deficit model can become problematic if and when the view of science as an epistemic authority is not shared among communicators.

It is important to note that the deficit model is inadequate as a means for establishing the epistemic authority of science:

> As with other beliefs, then, the assignment of epistemic authority may involve the joint influence of informational and motivational factors. Thus, the mere presence of relevant information may not suffice to produce an impression of epistemic authority. In addition to the information being "given," one would need to be motivated to "take it." (Kruglanski et al., 2005, p. 355)

A key example of this inadequacy can be found in the anti-vaccination movement. This movement has had moderate success in Europe and the United States, despite repeated efforts by medical professionals to inform the public about the safety and necessity of vaccination (Kata, 2010). Following the deficit model and providing anti-vaccination audiences with scientific information are likely ineffective in some cases because these audiences either question the epistemic authority of science or are more persuaded by non-scientific influences (Poland, 2011).

Affording science epistemic privilege is, I argue, one of the most powerful and underexplored factors serving to support the use of the deficit model in science communication. Previous work has examined the connection between epistemic authority and communication (Origgi, 2008). In addition, recent work within science communication has utilized epistemic authority as a framework to understand how competing voices battle with science for epistemic voice (Harambam & Aupers, 2014) and the a priori decision to trust sources other than science (Hildering, Consoli, & van den Born, 2013). Even so, very little work exists that examines the role of epistemic authority as a meta-theoretical structure for science communication scholarship, particularly within communication studies. Notably, there are some academic disciplines that address these issues that could provide guidance for science communication scholars to move in this direction, including the philosophy of science and science and technology studies.

Summary

Taken together, these three factors serve to support the persistence of the public deficit in science communication research and practice to greater and lesser extents across a variety of contexts. Importantly, these factors do not exist in isolation, nor do they exist in any kind of causal structure. Rather, they coexist and reinforce each other. For example, how we understand science as a phenomenon greatly impacts our understanding of scientific knowledge, and vice versa. Similarly, how we conceptualize scientific knowledge impacts how we view the role of communication in promoting that knowledge which, in turn, impacts how we conceptualize knowledge and so on. While some academic efforts attempt to refine and address these issues (as noted above), there is plenty of work left to be done within science communication research and practice.

Discussion

As highlighted throughout this article, the deficit model is not in and of itself problematic, and there is ample evidence that supports the utility of the public deficit as a construct (Miller, 2010). What is more, it is not the case that alternative models (e.g. dialogue, knowledge co-production) remedy all of the shortcomings of the deficit model (Bucchi, 2008), nor does the presence of alternatives indicate that the deficit model is obsolete. According to Brake and Weitkamp (2010), "[not all] science communication activities need to involve dialogue. Strategies that inform the public of new scientific research or excite the public about scientific discoveries are still important" (p. 2). Wright & Nerlich (2006) mirror this sentiment:

> Success in studying the influence of contextual factors on the public understanding of science has raised the hope that the deficit model will soon, to borrow a term from Trotsky, be consigned to "the dustbin of history." Indeed, it is tempting to discuss the use of the deficit model as an archaic model, long replaced in the march of progress that characterizes the social study of "making sense of science." However, the outright rejection of the deficit model in favor of "alternative" explanations of the public understanding of science overlooks the importance of the deficit model as a shared cultural resource used to discuss science. (p. 332)

Other scholars have agreed and highlight that the deficit model can coexist with other communication models (Trench, 2008). I echo these sentiments and argue that the deficit model is a necessary, though not sufficient, model for science communication. The deficit model is particularly useful, for example, when communicators concurrently assume the epistemic authority of science. There are key areas for future research that may aid in using the deficit model more suitably and developing new methods for communicating science.

Future research

In contrast to the practice of communicating science, science communication as an academic endeavor is fairly new (Bucchi, 2008). In recognition of our youth as an academic field and the factors outlined above, I contend that there are two key opportunities for future research. First, it is clear that the absolute rejection of the deficit model is not appropriate (Wright and Nerlich, 2006) nor is the unconditional application of alternative dialogic models (Brake and Weitkamp, 2010). Furthermore, it remains unclear "under what conditions ... different forms of public communication of science emerge" (Bucchi, 2008: 70) or under what conditions they ought to emerge. Moving forward, science communication scholars ought to focus on how to effectively utilize different communication models (e.g. diffusion, dialogue, participation) within different communicative environments. This charge undoubtedly requires that science communication scholars focus on developing methods for understanding and evaluating science communication contexts in new and innovative ways.

Second and related to this call, I contend that engaging in a deeper evaluation of the role of epistemic authority in science communication research and practice is paramount. A small number of scholars have noted that the deficit and dialogue model hold scientific knowledge as the epistemic standard of knowledge production (Bucchi, 2008). Given this epistemic supposition,

> the need has been invoked for another, more substantial shift to a model of knowledge co-production in which non-experts and their local knowledge can be conceived as neither an obstacle to be overcome ... nor an additional element that simply enriches professional expertise ... but rather as essential for the production of knowledge itself. (Bucchi, 2008: 68)

That is, there is a need for science communication scholars to reevaluate the underlying assumption that science is the epitome of knowledge production. To aid in this reevaluation, I argue that we ought to first understand how epistemological assumptions impact science communication processes and outcomes, if they do at all. It is likely the case, for example, that affording science epistemic privilege significantly impacts science communication in some contexts, but not in others. Additionally, within contexts that it does have an impact, we need to understand the nature and magnitude of that impact before we cultivate and advocate for epistemologically sensitive science communication practices. There is existing work that looks at epistemic authority indirectly through issues of trust and information sources (e.g. Buys et al., 2014), but a more specific focus on epistemic authority is warranted.

In addition to key opportunities for future research, there is considerable room for theoretical development within science communication scholarship, particularly within communication studies. First, scholars ought to have a critical conversation regarding the overall ethos of science communication scholarship. While I contend, as explicated above, that science communication scholarship carries with it an ethical responsibility to foster and improve the relationship between science and society, a critical examination of this commitment is warranted. More specifically, science communication scholars ought to have spirited debates about the place of science in society, the assumptions and implications of its promotion, as well as our implicit ethical assumptions and commitments. In addition, scholars ought to engage in a discussion regarding how they define and understand science as an endeavor, including a critical examination of the place of scientific knowledge in different contexts. These debates are already taking place in similar fields, as noted above, and we would do well to echo their efforts.

Second, scholars ought to critically examine how communication is conceptualized as a phenomenon. As highlighted above, diffusion is the most ubiquitous conception of communication in science communication scholarship. As long as communication is viewed as the diffusion of scientific information, the deficit model will continue to be predominantly (and inappropriately) utilized. There is incredible diversity and nuance among communication theorists regarding what communication is, what it ought to be, and how it functions (St. John, Striphas, & Sheperd, 2006). Assuming science communication scholars echo communication theorists' contention that "it matters whether we take communication to be one sort of phenomenon or process or idea ... or another" (St. John et al., 2006, p. xi), a critical examination of this sort would only be beneficial to our field as a whole.

Conclusion

In this article, I argue that there are three key factors that drive the continued use of the public deficit model within science communication research and practice: the purpose of science communication, how communication as a phenomenon is conceptualized, and how science and scientific knowledge are defined. It is important to note that the use of the public deficit is not, in and of itself, problematic. However, it is not suitable for all science communication contexts, and more research ought to focus on how to better characterize science communication contexts and better utilize different communication techniques within those contexts. I suggest that this process can be greatly aided by focusing on the role of epistemic authority in science communication processes and outcomes.

CHAPTER TWO

"WE WILL HAVE LED THE HORSES TO WATER…" EPISTEMIC AUTHORITY AND SCIENCE COMMUNICATION IN SUSTAINABILITY SCIENCE: UNDERSTANDING RESEARCHERS' PERSPECTIVES

Introduction

Coastal resources contribute more than $222 billion to the United States economy through fishing, recreation and tourism (NRDC, 2012), and play an integral role in maintaining ecological diversity and cultural identity. The northeastern state of Maine exemplifies the importance of coastal resources through its shellfishing industry, which contributes more than $300 million annually to Maine's economy and plays a crucial role in shaping this rural state's cultural identity. Bacterial contaminates, including fecal coliform, represent a threat to the sustainability of Maine's coastal resources. Out of the 200,000 acres of mudflats in Maine, shellfish harvesting is restricted or entirely prohibited in 174,000 of those acres (approximately 87 percent) due to bacterial contamination. These contaminants can cause illness in beachgoers and contaminate shellfish, making them unsafe to consume. Coastal water quality testing and management play a key role in ensuring the sustainability of these resources.

Complex socio-ecological problems, like bacterial pollution in Maine and New Hampshire, often require that scientific researchers collaborate with individuals and organizations outside of their own disciplines and, oftentimes, outside of academia entirely. This postnormal mode of scientific research (Funtowicz & Ravetz, 2003) encourages university researchers to engage in participatory models of engagement, where nonscientific publics and scientists working outside of academe are invited to co-produce knowledge and, through collaboration, arrive at solutions for sustainability. Science is no longer viewed as the center of contemporary knowledge production within this participatory model of engagement. Instead, the process of producing knowledge occurs by bringing diverse types of knowledge together, where for example scientific knowledge combines with traditional ecological knowledge (e.g. Fang, Hu, & Lee, 2015). Parallel epistemic shifts have occurred in science communication, where a participation model the deficit and dialogue model of science communication are theoretically sidelined in favor of the participation model, which invites diverse groups of stakeholders to play a more democratic role in science by offering critiques, assessing implications, or negotiating meaning (Trench, 2008).

Participatory models of engagement are particularly popular within sustainability science, where the incorporation of diverse needs, perspectives, and knowledges serves to advance effective problem solving. Previous work has argued for participatory models of engagement to avoid epistemic imbalance. However, few studies examine researchers' perspective on science and alternative forms of knowledge in conjunction with their engagement behavior. This kind of work is especially important given that the epistemic privilege of science can function as a significant barrier to the creation of meaningful solutions, particularly when it comes to persuading diverse groups of people to buy-in to one particular solution over another in complex sustainability-related contexts.

This study mobilizes the concept of epistemic authority and science communication theory to examine researchers' perspectives on scientific knowledge and engagement within a large, sustainability-focused research team in New England. Our results demonstrate the potential complexity inherent for researchers who maintain science's epistemic authority to integrate nonscientific perspectives meaningfully into their work. In addition, our results challenge the presumed role of participatory models of stakeholder engagement within sustainability science. We initially provide background on the field of sustainability science, introduce the concept of epistemic authority, and provide an overview of the science communication framework that guides our analysis. We then introduce study methods and provide study results. Implications, limitations, and opportunities for future research are discussed.

Literature

Sustainability science

The past few decades have brought with it what some scholars term a new social contract for science (Lubchenco, 1998; Ravetz, 1999), where traditional scientific methods of knowledge production are deemed inadequate in terms of their ability to address the complex social, ecological, and economic issues that threaten Earth's life support systems. Scholars have called for a shift in how we theorize and conduct science so that we can advance our ability to "…deal with many of the current and emerging more complex and 'messy' situations and issues characteristic of the problems of 'organized complexity'" (Gallopin et al., 2001, p. 221). Sustainability science targets these complex, interrelated, and messy social, environmental, and economic conditions. As a field, it attempts to generate a better understanding of complex systems characterized by a multiplicity of perspectives, non-linearity, systematic emergence, self-organization, multiplicity of scales, and irreducible uncertainty (Gallopin et al., 2001). Sustainability science has varying definitions (e.g. Jerneck et al., 2010; Kajikawa, Tacoa, & Yamaguchi, 2014; Komiyama & Takeuchi, 2006). For the purpose of this paper, we follow the Proceedings for the National Academy of Science's definition of sustainability science: "… an emerging field of research dealing with the interactions between natural and social systems, and with how those interactions affect the challenge of sustainability: meeting the needs of the present and future generations while substantially reducing poverty ad conserving the planet's life support systems" (Asner, G., Bebbington, A., Bloom, B., Chapin, S., Clark, W., DeFries, R., Hanson, S., McCay, B., Moran, E., Polasky, S., Schellnhuber, H., Turner, 2016).

Sustainability science aims to modify and improve "not only the diffusion and use of scientific findings, but also in the way science itself is performed" (Gallopin et al., 2001, p. 227) by making it more salient, credible, and legitimate within the world of action (Cash et al., 2003). This includes considering different "epistemologies" (i.e. traditional ecological knowledge) within the knowledge production process (Gallopin et al., 2001). Researchers are encouraged to communicate with diverse stakeholder groups in an attempt to access and incorporate diverse knowledge types in the process of creating sustainable solutions (Lang et al., 2012). Previous work has discovered a wide variety of partnership preferences (Hutchins, Lindenfeld, Bell, Leahy, & Silka, 2013) and frameworks for engagement (Lang et al., 2012) within sustainability science.

Sustainability scholars have characterized stakeholder engagement using various models and metaphors, including boundary work (Guston, 2001), knowledge co-production (Cornwell & Campbell, 2012), going beyond panaceas (Ostrom, Janssen, & Anderies, 2007), and community engagement (Weerts & Sandmann, 2010). Despite the variability in models and metaphors for stakeholder engagement, they all echo a central tenet of sustainability science: science is not and ought not to be the end-all-be-all of knowledge production within the context of contemporary problem solving, and participatory models of engagement are the recommended cure.

Examples of sustainability science are varied and multiple. This study focuses on the New England Sustainability Consortium's (NEST) Safe Beaches and Shellfish Project. NEST is a large transdisciplinary sustainability consortium between The University of Maine and The University of New Hampshire funded by the National Science Foundation's Experimental Program to Stimulate Competitive Research (EPSCoR). EPSCoR's objective is to broaden direct participation of diverse individuals and organizations in scientific research and foster effective engagement of project participants and partners. NEST's Safe Beaches and Shellfish Project is the first iteration of this consortium, and aims to strengthen the scientific basis for decision-making surrounding beach and shellfish flat management and closures in Maine and New Hampshire. NEST brings together the expertise of social, economic, and biophysical researchers, and includes a host of stakeholders, including individual citizens, nonprofit organizations, and state agencies[1]. NEST's Safe Beaches and Shellfish Project is a particularly appropriate example of sustainability science to study because it is generated within an applied context, it incorporates nonscientific stakeholders into the research process, it is interdisciplinary, and it is dedicated to creating tangible, lasting sustainability solutions.

Epistemic authority

Given that sustainability science emphasizes the importance of egalitarian knowledge production, it is important to examine the concept of epistemic authority. Epistemic authority refers to the supremacy afforded to a particular source in the process of knowledge production, acquisition, and subsequent decision-making. A source has epistemic authority when it is "a source on whom an individual may rely in her or his attempts to acquire knowledge on various topics" (Kruglanski et al., 2005, p. 351). Epistemic authority is constructed, maintained, and dissolved through communication (Origgi, 2008), and "the value of our knowledge claims varies as the stakes of the contexts of communication vary" (Origgi, 2008, p. 36). Epistemic authority is an important concept because it enables us to think about how we attribute authority and power to whom or what when we engage in the world.

People afford epistemic authority to a variety of different sources for different reasons, including the desire to see a source as authoritative (e.g. a religious leader) or the need to affirm one's own beliefs and views (Kruglanski et al., 2005). Most epistemic authority is context-specific, in that it only maintains authority in very specific domains.

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[1] See http://www.newenglandsustainabilityconsortium.org/ for more information

For example, one might assume an oceanographer to be an epistemic authority regarding rising sea temperatures, but they would not necessarily extend that authority to include the oceanographer's opinion on the ramifications of capitalism in the Western world. However, some epistemic authority is much broader in nature, and those to whom it is afforded can hold influence in numerous life domains. These authorities could include, for example, therapists or religious leaders.

Affording any source epistemic authority can have an immensely powerful influence on an individual's judgments and behavior (Kruglanski et al., 2005) and her/his environmental decision-making. Scientific knowledge is, by and large, considered the epistemic authority on a vast array of topics (Gauchat, 2010). Though it is important to note that we must challenge and renegotiate this authority at times (e.g. climate change, vaccinations), it remains a key component of Western knowledge production and policymaking (O'Brien, 2013). Importantly, the epistemic privilege of science can function as a significant barrier to the creation of meaningful solutions, particularly when it comes to persuading diverse groups of people to buy-in to one particular solution over another in complex sustainability-related contexts.

Science communication framework

This epistemic shift is not unique to sustainability science. Science communication as a field has similarly argued for the use of a participatory model of engagement to improve science-society relationships. Science communication scholars have defined three communication models (i.e. modes of engagement) in science communication research and practice: diffusion (i.e. deficit), dialogue, and participation (i.e. knowledge co-production, conversation) (Bucchi, 2008). The first two, diffusion and dialogue, have been criticized for maintaining the epistemic authority of science, meaning that they privilege science fundamentally over any other form of knowledge. The participative model of science communication, like participative models of stakeholder engagement, challenges this authority and encourages the co-mingling of scientific and nonscientific knowledges. Echoing the work of Hetland (2014) and others, we contend that these three communication models, while discussed independently here, are not mutually exclusive or separate categories. Rather, they exist as a part of a continuum for science communication practice, "in which the boundaries between neighboring options are porous and shifting" (Trench, 2008, p. 130).

The diffusion (i.e. dissemination) model is the most commonly used communication model, both within and outside of science communication scholarship. Diffusion uses the traditional, linear, one-way model of communication (Shannon & Weaver, 1949), and assumes that the ultimate goal of communication is the *acquisition and utilization* of scientific information by scientific and non-scientific audiences. The diffusion model encompasses what scholars have labeled the deficit model of science communication, where the public is seen as a passive consumer of information "whose default ignorance and hostility to science can be counteracted by the appropriate injection of science communication" (Bucchi, 2008, p. 58). The deficit model assumes "that public skepticism toward modern science is caused by a lack of adequate knowledge about science… [and] this skepticism… can be overcome by providing sufficient information to the public" (Besley & Tanner, 2011). The goal of this one-way communication is to provide passive, nonscientific audiences with "selected nuggets of high-quality [scientific] knowledge" (Gregory, 2011, p.307) in an effort to change their opinions about science or change their behavior. Examples of the diffusion model include mass media communication (e.g. newspapers or television), traditional scientific journal articles, or technical reports.

Scholars have heavily criticized the diffusion model for being overly simplistic (Bucchi, 2008; Hansen et al., 2003; Sturgis & Allum, 2004), remaining largely ineffective (Holland et al., 2007; Nisbet & Mooney, 2007), and unfairly characterizing those opposed to scientific activities or endeavors as necessarily deficient or ignorant (Bucchi, 2008; Priest, 2001). In light of these critiques, both research (Tøsse, 2013) and practice (Davies, 2008) still utilize these concepts widely. Many scholars, ourselves included, echo the necessary (though not sufficient) role diffusion plays within contemporary science communication practice (e.g. Sturgis & Allum, 2004; Trench, 2008).

The dialogue model serves as an effort to remedy the shortcomings of the diffusion model. Rather than a one-way transmission of information from experts to lay audiences, the dialogue model promotes two-way communication between scientific experts and various publics with the goal of creating shared understanding between communicators. Importantly, the dialogue model provides a space for nonscientific publics to have a voice in scientific processes and outcomes. Examples of the dialogue model in science communication include online interaction between experts and lay audiences (e.g. social media), or science centers and science museums (Bandelli & Konijn, 2013).

The dialogue model offers an alternative to the diffusion model, it falls short in two key ways. First, it does not explicitly encourage producers of scientific knowledge to engage with or consider alternative methods of knowledge production, and it maintains the dissemination model's "obsession with demarcating lay knowledge and the only knowledge of any value: that which warrants the term 'scientific'" (Bucchi, 2008, p. 68). Even when nonscientific expertise is considered, it is often judged against a scientific rubric, particularly in practice (Holm, 2003). Second, some scholars criticize dialogue for merely being a "refinement rather than replacement of a dissemination model" (Trench, 2008, p. 128), in that the feedback dialogue provides may be, above all, "a means to retune the talking-to; the listening may be more for improved targeting than for learning… the sender retains primary control; all that has been added is a feedback loop" (Trench, 2008, p. 128). In short, the dialogue model is often criticized for functioning more like a two-way deficit model, wherein scientific privilege can still be maintained and stakeholder feedback is utilized merely to improve the process of disseminating scientific knowledge.

As a result of these criticisms, many science communication scholars, like Bucchi, have called for an additional shift beyond the dialogue model in an effort to be more inclusive of alternative methods of knowledge production:

> The need has been invoked for another, more substantial shift to a model of knowledge co-production in which non-experts and their local knowledge can be conceived as neither an obstacle to be overcome by virtue of appropriate education initiatives (as in the deficit model), nor an additional element that simply enriches professional expertise (as in the… dialogical model), but rather as essential for the production of knowledge itself. (Bucchi, 2008, p. 68)

The shift beyond dialogue necessitates a greater role for non-scientific audiences in the process of knowledge production. Often referred to as “conversation” or “knowledge co-production,” the science communication model of participation aims to be more inclusive of non-scientific perspectives by creating a more democratic mode of authentic engagement.

The participation model necessitates that “communication about science [take] place between diverse groups on the basis that all can contribute, and that all have a stake in the outcome of the deliberations and discussions” (Trench, 2008, p. 132). Participation moves beyond the one-way and two-way models of communication, and embraces a multidirectional approach to communication, where the public is not only invited to provide feedback, but also engage in a serious discussion about issues, agendas, and meanings (Trench, 2008). The participation model assumes a practice of science “that is open and reflexive, where boundaries between disciplines and between science and non-science are increasingly porous” (Trench, 2008). We see this model is most often within postnormal contexts like sustainability science, or within topic areas where “knowledge derived from scientific research is just one ingredient of public policymaking and debate” (Trench, 2008, p. 126). This model often includes inviting the public to contribute to the “why” and “why not” of science, puts science under the scrutiny of other intellectual disciplines and cultural activities, and allows the public to offer insights into the public meaning(s) of science.

The participation model differs from the diffusion and dialogue model in that it embraces public expertise and nonscientific knowledge as an essential component to the knowledge production process and problem solving, and does not privilege scientific knowledge over other types of knowing (e.g. local ecological knowledge, occupational experience, etc.). Fundamentally, it does not grant a different level of epistemic authority to science, as the other two models do. In addition, as the name suggests, the participation model assumes that the public should be *actively* involved in the knowledge production process, beyond simply providing feedback to enhance scientific processes and acceptance. In short, mirroring efforts in sustainability science, the science communication model of participation assumes the public the play a more democratic role in the production of knowledge, going so far as providing critiques of scientific processes, assessing implications, or negotiating meaning (Trench, 2008).

Summary and study purpose

Both sustainability science and the participation model of science communication have a similar goal: to be more inclusive of alternative (i.e. nonscientific) perspectives and methods of knowledge production. Remarkably, very little work has examined researchers' perspectives on the epistemic authority of science within sustainability science contexts, which stands to impede meaningful engagement and the creation of shared solutions. Generally, researchers are expected to incorporate diverse knowledges and perspectives into sustainability science processes without ever having to critically examine their own assumptions about the epistemic authority of science. Science training models tend to grant significant epistemic authority to scientific knowledge over all other kinds of knowledge (although this is shifting). Here, we seek to understand how a group of scientists engaged in sustainability science actually perceive epistemic authority, when the fundamental goal of their research is to link knowledge with action by engaging directly in knowledge production with individuals outside of university research.

We argue that analyzing researchers' epistemic perspectives and engagement behaviors can provide a clearer window into the role of epistemic authority and engagement within sustainability science. This kind of work will help us understand how a group of researchers aiming to produce integrated knowledge for the purpose of creating sustainability solutions actually perceive knowledge production and scientific authority. Which, we argue, carries "considerable applied significance" (Kruglanski et al., 2005, p. 357) for sustainability science practice. As such, our first research question is:

> RQ1: Do researchers who participate in sustainability science assume science to have epistemic authority?

Despite the clear role of communicating science, there is little work that examines researchers' engagement behavior in sustainability science contexts through a science communication lens. Given the parallel goals of participatory modes of engagement within sustainability science and the participatory model of science communication, this study uses science communication theory as a framework to address our second research question:

> RQ2: Do researchers who participate in sustainability science utilize a participatory model of science communication?

Examining these two concepts, epistemic authority and communication, in tandem is particularly appropriate given that the two are inextricably linked (Origgi, 2008).

Method

We conducted 26 semi-structured interviews with researchers working with the New England Sustainability Consortium's (NEST) Safe Beaches and Shellfish Project to address these questions. Participants were strategically selected based on their professional position and level of involvement in conducting research (only faculty and graduate students were eligible), length of participation within NEST (each participant had to be involved in the project for more than one year), their area of expertise (i.e. social or biophysical), and their home institution. We used a purposive sampling technique in an effort to get representation from each area of scientific expertise included in the project, gender balance, and representation from both universities. Participants were contacted via email and invited to participate. Out of the thirty-three researchers who were invited to participate, twenty-six agreed. Interviews were recorded and transcribed, and they ranged in duration from 25 to 105 minutes.

The interview protocol consisted of three groups of questions. The first group focused on the specific details of the participants' work and their perception of science and scientific knowledge. Sample questions include:

> *"What do you see as the value in doing scientific research?"*
> *"What motivates you to do this kind of work?"*
> *"Does scientific knowledge differ from other types of knowledge? If so, how?"*

The second group of questions asked participants to talk about their experience communicating with stakeholders within the context of the NEST project. Sample questions include:

> *"What is the purpose of communicating with stakeholders?"*

"When communicating with stakeholders, what kind of outcomes are you looking for?"
"When communicating with stakeholders, are there particular communication strategies that have worked well?"

The third group of questions asked participants about their perceptions of the overall goals of NEST, the project outcomes they anticipate, the communication efficiencies and challenges they have experienced on the team, and their overall satisfaction with team dynamics and decision-making. Sample questions include:

"What are the desired outcomes for NEST from your perspective?"
"How would you characterize the communication on NEST?"
"What would it take for you to call this project a success?"

Participant responses from all three sections were included for this analysis, as most participants discussed stakeholder engagement and their perception of scientific knowledge throughout the entire interview.

Data analysis

Interview transcripts were coded to sentence level in two phases using NVivo 10. First, transcripts were analyzed for any reference to scientific knowledge or other knowledge types (i.e. traditional ecological knowledge). Transcript data that addressed science or scientific knowledge, or the role of scientific knowledge within addressing sustainability problems, were coded as either *affirming* epistemic privilege (i.e. "science is the best way to solve problems") or *denying* epistemic privilege (i.e. "I would not say that scientific knowledge is different than any other type of knowledge").

Second, transcripts were coded for the three science communication models outlined above. Text was coded as *diffusion* if the participant referenced one-way communication between themselves and stakeholders with the goal of persuading the public, promoting scientific knowledge, or altering stakeholder perceptions or behavior. Text was coded as *dialogue* if the participant referenced two-way communication with stakeholders in an effort to better understand stakeholder needs and perspectives. Text was coded as *participation* if the participant referenced using communication as a method for setting the agenda for scientific research, or if the participant referenced using communication as a method to allow stakeholders to debate the meaning(s) of scientific knowledge.

Results

<u>The epistemic authority of science</u>

In our first research question, we asked: Do researchers who participate in sustainability science assume science to have epistemic authority? When directly asked whether or not scientific knowledge differed from other knowledge types, approximately half of the participants promptly denied the epistemic authority of science, while half affirmed the uniqueness and authority of science. Interestingly, even though we did not directly ask participants whether they thought scientific knowledge was better or worse (they were merely asked if they thought it was different), almost every participant compared it to other knowledge acquisition methods (e.g. experience) and ranked science accordingly. Participants used words like *better*, *more*, *reduces,* or *increases*, indicating a reference point for science that relied on comparing it to other knowledge sources.

Participants who *affirmed* the authority of science did so in three key ways. First, most participants referenced the scientific method or discussed how the scientific process of knowledge creation was more structured or reliable than other types. For example, one participant explained:

> I think perhaps in how it's created and how we understand it, how we understand it to be using scientific methods. So, as opposed to, there's a lot of other types of, I don't know whether it's knowledge or beliefs that are not derived in the same way and wouldn't stand up to the type of scrutiny, and yet, at the same time, may have a lot more weight in a decision.

Second, a handful of participants explained how scientific knowledge differed from other types of knowledge in its empiricism and commitment to concepts like objectivity and validity:

> … science begins with an observation or a statement of how things work which comprises some theory and that theory becomes testable and a testable theory survives tests of its validity. Not all knowledge is based on that principle. There are whole realms of knowledge that require no empirical basis whatsoever and that is what sets science apart.

Third, participants affirmed the uniqueness of scientific knowledge by referencing the role of uncertainty and skepticism within the scientific process. For example, one participant stated:

> So to me when you say is science unique, I think yes, but in a very broad way in that here's an idea. I'm willing to be critical of the idea… the idea of playing devil's advocate with yourself and really challenging your ideas. So one of the reasons I do fairly well when I do science is because I walk in and go 'how could I be wrong, how else could it be interpreted, what data would I have to collect to convince myself that that's not true?

Notably, a handful of participants who *affirmed* the authority of scientific knowledge did so hesitantly. The hesitance to proclaim the superiority of scientific knowledge is evident in the following quotes (emphases added):

> I think things like science – and now I mean science like – actually let me be the – well, no***. I don't know quite how broad I want this to be***. I wish more people could do useful things in the world, and particularly for science, but many for –

> and there I think I certainly mean natural science, social science, engineering. But I'm just in conversations with folks in the humanities and the arts, it seems like we have a lot of knowledge and insight that if we could figure out that we could do more with it if we tried, that would be useful to the world… Useful, I guess, probably one sort of sense is ***that [science] helps make things better, do a better job of solving problems, make things less worse***.

> I mean, I think knowledge is knowledge. ***I don't really know how to answer that question***. But I think non-scientists think a lot differently.

> No, ***well I'm gonna be measured in my response***. You've set me up, like I have to come up with some pithy answer. No, this is like basic stuff that I could probably give you a textbook answer, but I'm gonna try to give you a nuanced one based on my understanding.

> Scientific knowledge maybe has – ***I don't want to say an advantage*** – a more structured approach to it, maybe it is more of just a methodological method in terms of how you approach and how you think about gaining new knowledge.

These responses are significant because they point to an internal conflict between what their initial reaction *is* and what they feel their reaction *should* be. One participant directly referenced the stereotype of scientists assuming science is superior when s(he) was asked about the uniqueness of scientific knowledge:

> That's an interesting question. No, knowledge is knowledge, and I think there's a real hierarchy of importance…. but I would say scientists think other people are just lesser mortals, because they're not smart like they are, they can't do math, and they don't know how to use computers, and they can't run fancy lab equipment. It's not necessarily stated and it's not universal, but you certainly get that feeling. It's a stereotype.

Another participant reinforced the hesitation to answer the question, and went so far as to decline to answer, explaining that they did not feel qualified to respond.

Participants who denied the epistemic authority of science did so in a number of ways. Some did so on the basis that scientific knowledge is not always of use to society, as compared to other types of knowledge. For example, one participant explained, "by no means do I believe that pure basic fundamental knowledge derived by [scientific] research is more likely to be of value to society, and I bet empirically you could argue that it's been less useful.” Other participants referenced the importance of integrating scientific knowledge with other knowledge types in an effort to get a bigger picture of a problem or issue or be better equipped to solve environmental problems. For example:

> And I also feel like that different kinds of knowledge, scientific knowledge, non-scientific knowledge, they have their strengths and weaknesses. They both see parts of the picture, and I feel like bringing them together is what's important. That there's things that scientific knowledge can answer that other kinds of knowledge can't, and vice-versa.

Some participants went as far as saying that other knowledge types (e.g. traditional ecological knowledge) were *more* informative and useful than scientific knowledge. For example, one participant, while discussing the important knowledge beach-users hold regarding coastal environments, explained that they have a “wealth of knowledge about the environment” that scientists could not possibly have, “just because they’re in the water every single day.”

Interestingly, *every* participant who denied the epistemic authority of science when directly asked affirmed that authority elsewhere in his or her interview. Many participants who denied authority, for example, stated that they wanted more nonscientific stakeholders to utilize science within their decision-making, and insinuated that scientific-based decision-making was inherently superior to alternatives:

> Is science not getting into the hands of the decision-makers or are the people on the ground not able to communicate back to decision-makers what those conditions are so that they can be better – you know. This is the problem scape, I think, of the project. So yeah, just saying like, in terms of the overall effect of the project. I’d like to see that.

Most participants who noted the use of science in decision-making did so when they were asked about desired project outcomes. For example, one participant explained "ideally there would be some outcomes where the way that the state or local folks make a decision that is different based on the science." Another participant echoed this sentiment:

> [NEST] certainly is helping agencies and stakeholders think about how to work better and if there are rule changes that they could be doing. Whether or not that ultimately leads to that I don't know.

Similarly, other participants who initially denied the epistemic authority of science referenced the superiority of science by explaining that scientific knowledge would improve stakeholders' decision-making, and therefore improve coastal ecology. For example, one participant noted: "so for me, it's really about how can we do the right kind of science to figure out how we make it better in the future so that those shellfish beds and help it so that the beaches can open and be safe?"

Some participants directly contradicted themselves regarding the epistemic authority of science. For example, when asked directly if scientific knowledge was different than other types, one participant explained (emphasis added): "I wouldn't say that scientific knowledge is any different than artistic knowledge, athletic knowledge, social knowledge… *there's no one way to learn or do anything*." However, later on in the interview, when asked about the outcomes they would like to see for NEST, they asserted (emphasis added): "I think one of the most important assets to solving any challenge or public or social problems is that it has to be grounded in something that's directed, that has potential to aid in solving that problem. *And having that be grounded* *in scientific research is one of the surest ways to do that*." One participant, when asked if scientific knowledge was different, responded: "I think my gut answer would be no." Less than 20 seconds later, this same participant said, "but I mean, if you want good information, the way to get oftentimes… is scientifically."

Whether directly or indirectly, every single participant referenced the superiority of scientific knowledge over other knowledge types, even if they spent time explaining whey they did not believe that to be the case when directly asked. Surely, there was variability regarding the extent to which they believed science to be superior, and some participants were more willing to assert science's superiority than others. However, it is notable that, in a group of researchers who are working within the context of engaged sustainability science, all of them, to some degree, maintained the superiority of scientific knowledge over other knowledge types, particularly when discussing issues of state level decision-making and the health of coastal resources. Our goal here is not to criticize this group of scientists, but to highlight how complex epistemic perceptions are even among a group of scientists who expressly aim to integrate diverse forms of knowledge into the scientific process itself.

Modes of engagement

In our second research question, we wanted to know: do researchers who participate in sustainability science use participatory models of engagement? Results indicate that most NEST researchers use all three models of science communication, to greater or lesser extents within the context of their work. Contrary to conventional conceptions of sustainability science, however, participation was the *least* discussed mode of stakeholder communication and engagement. Dialogue was by far the most discussed communication model, followed by diffusion, and participation.

The vast majority of participants discussed mobilizing the dialogue model of communication when engaging with stakeholders. There were three key ways in which researchers on NEST mobilized the dialogue model of science communication: to understand stakeholder needs and perspectives, to reach a mutual understanding with stakeholders, and to establish, develop and/or nurture relationships with stakeholder groups. Researchers who employed dialogue in an effort to understand stakeholders' perspectives primarily did so early on in the research process in an effort to better understand the problem at hand and direct their own research accordingly. For example, one participant explained:

> Actually learning more about what's going on and their actual problems are, because what I think are problems might not be problems. They may be more concerned about other things. So getting that clarification and making sure we're working on the right problem and asking the right questions, that comes from talking to stakeholders in the first place, that joint defining of the research question.

Researchers also engaged in dialogue in an effort to reach mutual understanding between themselves and stakeholders. This differed from understanding stakeholder perspectives, in that it emphasized the need for stakeholders to understand the researchers' perspective as well. For example, one participant said: "So you just kind of come away with…that there's some clarity there that we both understand. You understand what I'm doing and I understand where you're coming from as well."

The third reason researchers employed dialogue was to increase their professional network. Here, communication became less about transmitting information back and forth between parties, and more about creating stable bonds with stakeholders that would last beyond the scope of the project. One participant highlighted this kind of communication:

> Because I have established relationships with people. That's an important part. They are colleagues or they're friends or whatever in some cases or just professional acquaintances. But [communication] builds networks. It brings connections. You find out about other people doing similar work or different work or whatever. You see them in meetings and then bring up something. So it just, the web of humanity, it's a way of connecting and the ones that are really good are great connections for a long time where they're fruitful in terms of meeting mutual interests.

Researchers who discussed dialogue often referenced doing so in the very beginning of the research process, and noted their intention to check in with their stakeholder partners toward the end of the project to fine-tune research outputs and stakeholder deliverables (e.g. decision-support tools).

The second most discussed communication model was diffusion. Diffusion took different forms for participants. First, participants discussed using communication to enlighten or correct stakeholders regarding scientific issues or topics. For example, one participant explained: “My overarching goal is just to continually emphasize the message that intact ecosystems and conserved ecosystems are much healthier than exploited ones.” A couple of participants noted that enlightening and correcting stakeholder groups did not always go over well. For example, another participant noted: “It's not always [a positive experience] for sure because some stakeholders are really not receptive at all to your message, and will call you names or impugn your integrity because the message is not what they want to hear.”

Participants also discussed utilizing diffusion as a method to provide stakeholders with scientific information or information about NEST-related work. For example, when asked about the purpose of communicating with stakeholders, one participant explained: “The purpose is, first of all, a researcher owes society at multiple levels some kind of explanation of what you do because we get paid to do it, we should feel compelled to let people know what we do just generally.” In addition, participants discussed using the diffusion model to influence stakeholders’ perceptions regarding NEST research, researchers, or the academic institutions sponsoring the research. Notably, very few researchers referenced utilizing communication as a method of defending themselves against stakeholders who harbor a “default ignorance and hostility” (Bucchi, 2008, p. 58) toward science. Most participants who mobilized the diffusion model did so to provide information, change perception, or encourage more environmentally sound behavior.

Participation was the least discussed of the three communication models, though it was certainly present within the interviews. Most participants who described a participation model did so in an effort to aid in the development of more comprehensive sustainability solutions:

> I have a feeling that a focus on more than just accumulating knowledge and instead asking about what looks like a solution aiming out somewhere in that direction, engaging with stakeholders to get there, and mobilizing diverse ways of knowing will be part of many successful [communication] strategies.

Other participants who discussed using participation saw communication as a mechanism to acquire the expertise of stakeholders and integrate that knowledge into their research. As one participant explained, they engage with stakeholders because “the people that are on the ground, for me, working with shellfish every day, they know of a heck of a lot more about this than I ever will, because they have the experience.”

The participation model was also referenced as a way to push back against a diffusion model. For example, one participant explained:

> I hate this word persuasion in this context. Well you’ve got to persuade them that the science – no. We need to come to the table together, figure out how is your world view similar or different to or from mine? What can I learn from you? What can I and my team bring to the table that could help us craft a better future together?

Another participant echoed the concept of bringing knowledge “to the table,” explaining that communication “is the sharing of different expertise and saying, ‘Well, I know they have this expertise but I can bring some expertise to the table too.’”

The important distinction between dialogue and participation that arose within the interview data existed within the ultimate purpose of communication and engagement. For researchers who primarily engaged in dialogue, they did so in an effort to make the science they produced more user-friendly to stakeholder groups or to guide them in the right direction in terms of what type of research they should be doing. By contrast, researchers who primarily utilized the participatory mode of engagement did so to integrate stakeholder expertise into the creation of knowledge itself.

Discussion

This work stands to aid our understanding of sustainability science in three key ways. First, it highlights the need to be more deliberate about how we create organizations that attempt to combine different forms of knowledge. Given that sustainability science necessitates the inclusion of various epistemologies within knowledge production, this work highlights the potential complexity inherent for researchers who maintain science's epistemic authority to meaningfully integrate nonscientific perspectives into their work. Assuming that the goal(s) of sustainability science include integrating different forms of knowledge, and assuming researchers are in charge of said combining, understanding researchers' perspectives (explicit, implicit, or otherwise) of scientific knowledge in relation to other types of knowledge is important, as it could play a significant role in the success of engagement efforts and, therefore, the success of sustainability science. What is more, this work highlights the importance of having explicit and honest conversations about the role of science in contemporary problem solving and the merits of integrating alternative knowledges within sustainability contexts. Because the privileging of scientific knowledge can function as a significant barrier to the creation of meaningful solutions, this work points to the need for sustainability and other scientific organizations that aim to increase science-society integration to identify individuals who see the utility in alternative knowledge types and can meaningfully integrate scientific knowledge with other knowledge types (if such integration is to remain the overall goal of sustainability science).

Second, this work points to the utility of science communication theory in structuring stakeholder engagement within sustainability science. Analytical frameworks for science communication models (e.g. Trench, 2008) in particular allow a more nuanced understanding of communication needs and ongoing dynamics so that stakeholder engagement can be planned more effectively. Specifically, using science communication theory as a framework for engagement allows us to more efficiently systematize communication with stakeholder partners and keep better track of the communication dynamics that occur within sustainability contexts. Embracing this kind of systematized engagement, over time, will allow us to understand which communication dynamics are successful, which are not, and let us know when adjustments should be made. This kind of engagement framework will allow the identification of other variables that might impact engagement efforts. For example, it is possible that affording scientific knowledge epistemic authority in sustainability contexts can influence engagement behavior, and, ultimately, the ability of researchers to meaningfully integrate nonscientific perspectives into the sustainability science context.

Third, this work points to the utility of the concept of epistemic authority in sustainability science. Given that sustainability science necessitates the inclusion of various epistemologies, this work highlights the potential complexity for researchers who maintain science's epistemic authority to meaningfully integrate nonscientific perspectives into their work. This concept provides a window into researchers' perspectives on scientific and alternative knowledges, allowing us to have explicit conversations in sustainability science teams about the role of alternative knowledges and the relative value we will place on them. Though this was not the specific focus of this particular study, integrating the concept of epistemic authority into communication research could allow us to gain a deeper understanding of stakeholders' perspective on the role of scientific knowledge within their engagement and decision-making.

Integrating these concepts is conceptually appropriate given that communication allows us to "negotiate new epistemic standards by constructing together new reasons and justifications that are heavily influenced by moral, social, or political context and by the interests at stake on both sides, the speaker and the hearer" (Origgi, 2008, p. 35). Both of these outcomes, understanding researcher and stakeholder perspectives, can improve our ability to foster meaningful engagement and integrate diverse epistemologies, thus aiding in the creation of science that addresses societal needs.

Recommendations and key questions

This study highlights significant areas for discussion and key questions surrounding the methods and goals of sustainability science. First and foremost, this study challenges the pragmatism of equalizing epistemology in sustainability science; insofar as we assume those doing the engaging (i.e. researchers) ought to embrace this new contract for science at a conceptual level. The authors of this study suggest that it may not be realistic to expect researchers within sustainability science – or any other form of scientific knowledge production for that matter – to engage other knowledge types with the same value they afford to science. Perhaps we are asking scientists to speak out of both sides of their mouths and need to change the conversation altogether about what different forms of knowledge production do and do not produce. Rather than committing ourselves to the impossible idea of creating a world without hierarchy, we can hone our focus to understand the political, social, and cultural dynamics of how different forms of knowledge interact with each other in science-society contexts. The impossibility of creating an epistemic context devoid of hierarchy is particularly accentuated by the years (and, oftentimes, decades) of training researchers receive that guides them to conceptualize, produce, and evaluate knowledge in very particular (e.g. positivistic) ways. Simply trying to upend this thinking will continually place scientists – and the societies that need science – in an impossible bind. If the call for researchers to conceptually embrace this new contract for science is not universally feasible, is it still realistic to expect them to engage in meaningful participative modes of engagement where they are expected to afford alternative knowledges the same weight they do scientific knowledge? What is more, is it necessary for them to do so in order to accomplish the goals of sustainability science? We suggest the conversation itself needs to change and focus more on epistemic power dimensions themselves.

Second, while not the purpose of this study, this work highlights the need to examine critically the influence of funding agencies in terms of how sustainability science is accomplished and what knowledge "counts". The National Science Foundation (NSF), whose stated purpose is to promote the progress of science, funds the NEST Safe Beaches and Shellfish Project, as it does many other sustainability-related projects. This conflict of interest (of sorts) calls into question the role of funding agencies, who aim to promote science, in fostering participatory modes of engagement where science is, purportedly, brought down from its epistemic pedestal. What is more, because NSF and other funding agencies often require interdisciplinarity and engagement with nonscientific groups as a prerequisite for funding, there is always the possibility that researchers who secure such funding are merely paying lip service to participatory models of decision-making without engaging in serious reflection about the ramifications and feasibility of this type of engagement. Certainly, the issue of how we value different forms of knowledge comes to bear heavily in any efforts to link the production of scientific knowledge with societal decision-making. We can ill afford to ignore a conceptual bind in which so many scientists find themselves if we want science to become more relevant, responsive, and meaningful.

Finally, this study reinforces the constant need for sustainability scientists and proponents of postnormal science to engage in critical reflection and discussion regarding the purpose of participatory engagement and its role in creating solutions-oriented science. Unequivocally, this work raises the question: is sustainability science a step toward a new kind of knowledge production, or is it an attempt to further advance traditional science under the disguise of participatory rhetoric? What is more, is the lack of participatory modes of engagement a problem for sustainability science? Surely, it is possible to take the results of this work and conclude that the NEST Safe Beaches and Shellfish Project is merely an example of unsuccessful sustainability science. However, we contend that this is not the case, as the project functions much like other sustainability projects of its kind, and feedback from NEST's stakeholder partners has been overwhelmingly positive.

Limitations and directions for future research

This study provides a window into the epistemic assumptions and engagement behavior of researchers conducting sustainability science. Results challenge the assumed connection between epistemic authority and sustainability science, and the assumed role of participative modes of engagement within sustainability science. Even so, there are a few key limitations to note. First, this study focused on one particular research team focused on one particular aspect of sustainability, and, given the variability inherent in sustainability science efforts, may not be indicative of sustainability science as a whole. Second, this analysis rests on assumption that self-report accurately reflects researchers' true epistemic assumptions and engagement behavior, which may not be the case. For example, it is possible participants answered questions about stakeholder communication in terms of the overall goals of the project, rather than their actual communication behavior. Third and relatedly, our conclusions regarding which communication model was utilized rests on the idea that the more a participant talked about a particular mode of engagement, the more likely they were to utilize that mode of engagement, which may not be the case. Fourth, interviews were conducted one year before the scheduled end of the NEST Safe Beaches and Shellfish Project. As such, self-reported engagement behavior reflects only the first two years within the project, and could look different during the last year of the project. Fifth and finally, this work draws a parallel between participatory modes of engagement in sustainability science and the participation model of science communication. While both have significant theoretical overlap and ultimate goals, they may differ in ways that might influence our interpretation of participatory engagement within the NEST Safe Beaches and Shellfish Project.

This study highlights key areas for future research. First, while this study analyzed researchers' epistemic assumptions and engagement behavior, future work ought to investigate the *relationship* between these two concepts. That is, it might be the case that researchers' epistemic assumptions regarding scientific knowledge drive particular models of science communication and stakeholder engagement. Conversely, it might be the case that engaging in participatory models of engagement influences researchers' perception of scientific knowledge. Second, future work ought to examine how stakeholder partners within sustainability science projects perceive science and the role of scientific knowledge within their decision-making, and compare that information with researchers' perspectives. Implicit disagreement between researchers and stakeholders regarding the role (actual or desired) of science in decision-making could significantly impact collaboration, and understanding these dynamics in sustainability science could be beneficial. Finally, future work ought to compare sustainability science projects that mobilize varying engagement models and a diversity of epistemic views, in an effort to assess the extent to which an egalitarian epistemic environment and participatory modes of engagement are necessary components of sustainability science and the creation of effective sustainable solutions.

CHAPTER THREE

COMMUNICATING SCIENCE FOR COASTAL SUSTAINABILITY: EXPLORING THE RELATIONSHIP BETWEEN PERCEPTIONS OF EXPERTISE AND ENGAGEMENT PRACTICE

Introduction

Coastal resources contribute more than $222 billion to the United States economy through fishing, recreation, and tourism (NRDC, 2012), and play an integral role in maintaining ecological diversity and cultural identity. Complex environmental problems including ocean acidification (Stillman & Paganini, 2015), sea level rise (Moftakhari et al., 2015), rising sea temperature (Negri, Flores, Röthig, & Uthicke, 2011), and coastal pollution (Gu & Wang, 2015) threaten the social, economic, and environmental sustainability of coastal states. In Maine and New Hampshire, high levels of pathogenic bacteria contaminate beach water and shellfish flats, threatening coastal sustainability and posing a risk to public health. In an effort to assure the sustainability of New England's natural resources, including beaches and shellfish flats, researchers at the University of Maine and the University of New Hampshire formed the New England Sustainability Consortium (NEST). NEST aims to respond to societal challenges where social and economic goals need to be balanced with environmental protection. In doing so, NEST tackles environmental issues, including bacterial pollution, that upset the social, economic, and ecological sustainability of New England's natural resources.

NEST adopts a sustainability science approach, as discussed in greater depth in chapter two. This approach encourages researchers to collaborate with stakeholder groups and organizations outside of their own disciplines and outside of academia entirely (Hart & Bell, 2013; Lang et al., 2012; Nučič, 2012; Pohl et al., 2010; van Kerkhoff & Lebel, 2006). NEST researchers engage a wide array of stakeholder partners including local government, state government, tribal communities, non-governmental organizations, the private sector, and citizen scientists (New England Sustainability Consortium, 2014). Stakeholder engagement of this kind is generally maintained as the best method to incorporate diverse needs, perspectives, and knowledges for effective problem solving and the creation of sustainable solutions (Aakhus & Bzdak, 2015; Pomeranz et al., 2014; Ramachandra & Naha Abu Mansor, 2014). Connecting science with society needs through science communication plays a central role in stakeholder engagement. However, science communication theory is largely absent in sustainability science literature.

In practice, science communication is multifaceted and complex, and addresses a wide variety of sustainability contexts including climate change (Kakonge, 2013), ecosystem management (Castillo, 2000), nuclear energy (Fahlquist & Roeser, 2015), and forest resources (Zimmerman et al., 2006). This kind of variability precludes us from utilizing a one-size-fits-all approach to science communication practice (Trench, 2008). It remains unclear "under what conditions… different forms of public communication of science emerge" (Bucchi, 2008, p. 70), or under what conditions they ought to emerge. As such, there is a need to identify factors that impact science communication processes that can be utilized to improve science communication processes and outcomes. In this study, we employ a science communication framework to examine how researchers on NEST's Safe Beaches and Shellfish Project engage stakeholder partners within the context of their work. Specifically, we explore the link between researchers' perspectives on stakeholder expertise and their science communication behavior. To begin, we provide more detail about the NEST Safe Beaches and Shellfish Project. Next, we review pertinent literature including the different models of science communication and Collins & Evans (2008) periodic table of expertises. We then synthesize this literature and provide our research question and hypothesis, study methods, and results. Results suggest a significant positive relationship between how NEST researchers perceive the expertise level of their stakeholder partners and the manner in which they engage those partners. Study implications, limitations, and opportunities for future research are discussed.

Study context

This study focuses on the first iteration of NEST: the Safe Beaches and Shellfish Project. The Safe Beaches and Shellfish Project brings together researchers from University of New Hampshire, University of Maine, Keene State College, University of Southern Maine, College of the Atlantic, University of New England, Great Bay Community College, and Plymouth State University. This three year project brings social and biophysical researchers across these institutions together in order to strengthen the scientific basis for decision-making surrounding pathogenic bacterial pollution along the

Maine and New Hampshire Coast, including improving the process of closing of shellfish beds and posting of beach advisories.

Current coastal water quality assessment programs and subsequent decision-making procedures in both states are poor indicators of actual risk. As a result, public health is not sufficiently protected and shellfish beds are often closed far longer than they need to be, creating a significant economic loss for shell fishermen. NEST aims to develop a better understanding of how environmental conditions (e.g. rainfall events, topography, ocean temperature, water runoff, etc.) impact pathogenic dynamics and risk level for humans: “There is widespread agreement among resource managers and scientists in both states that current beach and shellfish management approaches are flawed; sustainability science research methods offer a means to address these flaws” (New Hampshire EPSCoR, 2016). NEST is funded by the National Science Foundation’s Experimental Program to Stimulate Competitive Research (EPSCoR). EPSCoR aims to diversify participation and organizations in scientific research and foster effective engagement.

The interdisciplinarity of research efforts, breadth of engagement activities, diversity of stakeholder partners, and commitment to advancing the use of science in decision-making make the NEST Safe Beaches and Shellfish Project an ideal consortium within which to study science communication dynamics. In the next section we overview the three models of science communication (diffusion, dialogue, and participation) and review Collins and Evans’ (2008) periodic table of expertises.

Literature

There are three science communication models utilized in science communication research and practice: diffusion, dialogue and participation (i.e. knowledge co-production) (Bucchi, 2008). To see a brief side-by-side comparison of each model, see Table 1. Echoing the work of Hetland (Hetland, 2014) and others, we contend that these three communication models, while discussed separately here, are not mutually exclusive, but rather exist as a part of a continuum: from the least amount of interaction between communicators (i.e. none) as in diffusion, to the most amount of interaction as in participation.

The diffusion model represents a one-way model of communication, where experts transmit scientific information to lay audiences with little or no feedback. Diffusion assumes that the ultimate goal of communication is the *acquisition and utilization* of scientific information by scientific and non-scientific audiences. Diffusion encompasses the deficit model of science communication, where the public is seen as a passive consumer of information “whose default ignorance and hostility to science can be counteracted by the appropriate injection of science communication” (Bucchi, 2008, p. 58). Examples of the diffusion model include, for example, the dissemination of scientific reports, the use of social media to disseminate scientific information, or science reporting within the mass media. The diffusion model has been heavily criticized, yet it remains widely utilized in both research (Tøsse, 2013) and practice (Davies, 2008).

Rather than a one-way transmission of information from experts to lay audiences, the dialogue model promotes two-way communication between scientific experts and various publics (Donghon Cheng et al., 2008). The dialogue model assumes that the ultimate goal of communication is the creation of shared understanding between communicators, the development of trust, and the strengthening of social relationships. Examples of the dialogue model in science communication include online interaction between experts and lay audiences, science centers, and science museums. The dialogue model addresses some of the shortcomings of the diffusion model in that it offers a mechanism for nonscientific audiences to provide feedback. It is important to note, however, that it only emphasizes public participation within *scientific* processes. The dialogue model does not explicitly encourage producers of scientific knowledge to engage with or consider alternative methods of knowledge production. As such, the dialogue model has been criticized for sharing the diffusion model's "obsession with demarcating lay knowledge and the only knowledge of any value: that which warrants the term 'scientific'" (Bucchi, 2008, p. 68). Even when nonscientific expertise is considered, it is often judged against a scientific rubric, particularly in practice (Holm, 2003). Examples of the dialogue model include interactive science centers and museums.

As a result of this limitation, science communication scholars have called for an additional shift beyond the dialogue model in an effort to be more inclusive of alternative methods of science communication that embrace nonscientific perspectives "as essential for the production of knowledge itself" (Bucchi, 2008, p. 68). The shift beyond dialogue necessitates a greater role for nonscientific audiences in the process of knowledge production. Often referred to as knowledge co-production, the science communication model of participation encourages communicators to be more inclusive of nonscientific perspectives within the process of knowledge production. The participation model is a multi-directional communication model which assumes a practice of science "that is open and reflexive, where boundaries between disciplines and between science and non-science are increasingly porous" (Trench, 2008). The participation model is most often used within postnormal science contexts, or within topic areas where "knowledge derived from scientific research is just one ingredient of public policymaking and debate, and scientists are called on to open 'science-in-the-making' for public scrutiny" (Trench, 2008, p. 126).

Table 1
Comparing Science Communication Models

	Diffusion	**Dialogue**	**Participation**
Communication Direction	One-way	Two-way	Multi
Goal	Information transfer	Feedback, shared understanding	Knowledge Co-Production
Level of Interaction (→)	*None*	*Moderate*	*Continuous*

Table 1

The participation model differs from the dialogue model in that it embraces public expertise as an essential component to the knowledge production process, and does not privilege scientific knowledge over other types of knowing (e.g. local ecological knowledge). In addition, as the name suggests, the participation model assumes that the public should be actively involved in the knowledge production process. The goal of communication within this model, then, is to ensure the active participation of the public and to combine scientific expertise with alternative knowledge types. Examples of the participation model of science communication are most prominent within sustainability science.

Expertise

In an effort to measure researchers' perception of stakeholder expertise, we use Collins and Evans' (Collins & Evans, 2008) periodic table of expertises. This table can be understood as a ladder of expertise, moving from ubiquitous expertise (knowledge that everyone has) to contributory expertise (knowledge very few experts possess). There are three types of expertise of interest here: primary source, contributory, and interactional (for a thorough review of meta-expertise and meta-criteria, see Collins & Evans (2008)). Table 2 provides a brief side-by-side comparison of each type of expertise.

Primary source expertise refers to expertise that comes from reading primary or secondary source literature (e.g. peer reviewed scientific studies) about a particular topic. *Interactional expertise* requires that one be able to not only engage with primary source literature, but also be able to master the language of a domain and carry on productive conversations with experts in a given arena. That is, interactional expertise requires "enculturation within a linguistic community" (Collins & Evans, 2008, p. 14), or the ability to talk the talk of a particular field. For example, we might describe a graduate student who can converse with professors about a particular research method, but has yet to carry out research utilizing that method, as having interactional expertise. Finally, *contributory expertise* necessitates that one is able to produce knowledge within particular arenas themselves, or that they are able to walk the walk of discipline-specific knowledge production. Individuals who possess contributory expertise include, for example, research professors or industry scientists.

Table 2
Expertise, adapted from Collins & Evans (2008)

	Primary Source	**Interactional**	**Contributory**
Definition	Knowledge derived from primary or secondary source literature	Enculturation within a linguistic community	Ability to produce knowledge within a particular arena
Propensity for Knowledge Production	*Minimal* →	*Moderate (linguistic)* →	*Full Contributor*

Table 2

Research question and hypothesis

The relationship between expertise and the three science communication models outlined above has been theoretically addressed in previous work (Hetland, 2014). However, very little work has tested the relationship between perceptions of expertise and actual science communication practice, particularly within a sustainability science context. As such, the research question that guides this study is:

> RQ: What is the relationship between NEST researchers' perception of stakeholder expertise and their science communication behavior?

That is, is there a relationship between how person A perceives person B's expertise about a topic, and how person A communicates with person B regarding that topic? All three science communication models embed particular assumptions about public expertise within them (Hetland, 2014). The diffusion model (which necessitates little or no interaction between communicators) assumes the least amount of public expertise, in that the model assumes the public lacks the knowledge they need. The dialogue model (which necessitates a moderate amount of interaction between communicators) assumes a moderate amount of public expertise, in that the model assumes the public competent in providing substantive feedback and engaging with scientific experts. The participation model (which necessitates continuous interaction between communicators) assumes the highest level of public expertise, in that public input is understood as central to knowledge production itself. As such, we propose the following hypothesis:

> H: There is positive relationship between researchers' perceived level of stakeholder expertise (from primary source to contributory) and their level of interaction with stakeholders (from diffusion to participation).
>
> H_0: There is no relationship between perceptions of stakeholder expertise and science communication behavior.

Method

Participants for this study included every active researcher within NEST's Safe Beaches and Shellfish Project, including professors, postdoctoral fellows, and graduate students. Data collection took place in two phases. Prior to this study, scales to measure science communication model use and perceptions of expertise had not yet been developed. As such, we conducted a series of semi-structured interviews to inform the development of survey items.

<u>Protocol development</u>

We collected qualitative data to get a better understanding of how NEST researchers mobilized the three science communication models to inform survey development. We used a purposive sampling technique in an effort to get equal representation from each area of scientific expertise included in the project, equal gender balance, and equal representation from both the University of Maine and the University of New Hampshire. Participants were contacted via email and asked to participate. Out of the thirty-three researchers who were invited to participate, twenty-six agreed. Interviews were recorded and transcribed, and they ranged in duration from 25 to 105 minutes. Interview data were transcribed and coded at the sentence level for the three science communication models outlined above.

There were three groups of questions in the interview protocol (see Appendix A for entire protocol). The first group focused on the specific details of the participants' work and their perception of science and scientific knowledge. The second group of questions asked participants to talk about their experience communicating with stakeholders within the context of the NEST project. The third group of questions asked participants about their perceptions of the overall goals of NEST, the project outcomes they anticipate, the communication efficiencies and challenges they have experienced on the team, and their overall satisfaction with team dynamics and decision-making. Participant responses from all three sections were included to build the survey questions, as most participants discussed stakeholder engagement throughout the entire interview.

Interview transcripts were coded to sentence level using NVivo 10. Text was coded as *diffusion* if the participant referenced one-way communication from themselves to stakeholders (e.g. “I communicate with stakeholders to provide them with information about the NEST project”). Text was coded as *dialogue* if the participant referenced two-way communication with stakeholders (e.g. “I communication with stakeholders to understand their perspective on coastal management”). Text was coded as *participation* if the participant referenced multidirectional communication in an effort to produce novel types of knowledge (e.g. “I communicate with stakeholders so we can all come to the table and produce knowledge together”). The coded material for each model was then compiled and turned into survey items. For example, if a participant indicated that they communicate with stakeholders in an effort to understand the type of research the stakeholder would like done, the corresponding survey item would be: “I communicate with this stakeholder to understand what type of research I/we should be doing.”

The survey protocol consisted of four sections (see Appendix B for entire survey protocol). The first section of the survey included items to measure researchers’ science communication behavior based on the three models outlined above (diffusion, dialogue, and participation), using a 5-point Likert scale of frequency: Never (1), Rarely (2), Sometimes (3), Often (4), Almost Always (5). To pretest the science communication model survey items for face validity, eleven social science researchers at the University of Maine (unaffiliated with NEST and unfamiliar with the current study) were provided with a randomized list of survey items and the operational definition of each construct (diffusion, dialogue, or participation). They were asked to group the items with the construct they believed to be the best fit, or indicate that the item did not fit in with any of the constructs. Out of the 36 items tested, 33 of them were consistently placed in the correct construct category. The three items that did not appear to have face validity were removed from the protocol prior to implementation.

The second section of the survey included items to measure researchers' perceptions of stakeholder expertise. Items for this section were developed using the operational definitions provided by Collins & Evans' (2008) Periodic Table of Expertises. Participants responded to each item using a 5-point Likert scale of agreement: Strongly Disagree (1), Disagree (2), Neither Agree nor Disagree (3), Agree (4), Strongly Agree (5). Sample items include:

> *In my experience, this stakeholder is able to use my disciplinary jargon effectively.*
>
> *This stakeholder has enough practical competency in my field that they can meaningfully contribute to my research.*
>
> *This stakeholder has done research in my field in the past.*

In section three, participants were asked to respond to statements about their motivation for engaging with stakeholder partners within the context of their work. In section four, they were asked to provide information about any prior training they have received in stakeholder engagement and their disciplinary affiliation (biophysical or social). Data from sections three and four were not included in this analysis.

The qualitative data in phase one indicated that the majority of researchers' mobilized more than one science communication models and engaged a multitude of stakeholder partners, making it difficult to isolate communication behavior and perceptions of expertise. In an effort to be as specific as possible, participants were asked to provide the name, occupation, and organization (if applicable) of their selected stakeholder, with the option to type "anonymous" if they preferred to keep the stakeholders' identity confidential. Doing this allowed researchers to focus on *one* stakeholder, rather than the multitude they may engage with, and provided the best way for us to isolate and measure perceptions of expertise and communication behavior.

Every active researcher on NEST's Safe Beaches and Shellfish Project, aside from the authors of this study, (n = 55) was invited via email to participate in an online survey through the Qualtrics survey system. We followed the tailored design method for participant recruitment (Dillman, Smyth, & Christian, 2014) and contacted participants across four weeks: a pre-notification email (week one), an initial invitation (week two), an invitation reminder (week three), and a final request for participation (week four). To complete the online survey, researchers were required to have communicated with a stakeholder(s) about their work within the context of NEST.

Analysis

Data were analyzed in SPSS, a statistical package for the social sciences. Science communication models and expertise were converted to ordinal, ranked data. To do this, survey item responses for each of the three communication models and the three levels of expertise were compiled to create an average score for each participant. Each participant was then assigned ranking by the communication model they employed most often (diffusion = 1, dialogue = 2, participation =3) and the level of stakeholder expertise they agreed with the most (primary source = 1, interactional = 2, contributory = 3). We then used a Spearman Rank Order Correlation analysis to explore the correlation between the two rankings across the 26 survey participants. Spearman's Rank Order Correlation was particularly appropriate because the data are ordinal and ranked, and the small sample size prohibited the assumption of normal distribution.

Results

Out of the 55 researchers who were asked to participate, 26 agreed, representing a response rate of 47 percent. Approximately half of the participants were researchers in biophysical sciences or engineering (n = 14), while approximately half were in the social sciences or humanities (n = 12). Participants held a mixture of professional positions, including assistant professors (n = 5), associate professors (n = 3), full professors (n = 6), graduate students (n = 7), and project administrators (n = 5). Demographic information including age, race, and gender were not collected.

Reliability of scales

All of the communication model subscales were found to be highly reliable. The diffusion subscale consisted of eight items ($\alpha = 0.921$), the dialogue subscale consisted of 13 items ($\alpha = 0.973$), and the participation subscale consisted of 10 items ($\alpha = 0.946$). Two of the expertise subscales were found to be highly reliable, and one was moderately reliable. The primary source subscale consisted of five items ($\alpha = 0.925$), the interactional subscale consisted of five items (α = 0.817), and the contributory subscale consisted of five items (α = 0.924). For a summary of subscale and item statistics for each of the six multi-item scales, see Table 3.

Table 3

Summary of Subscale and Item Statistics

Diffusion Subscale (α = 0.921)				
Survey Item	Mean	Standard Deviation	N	Chronbach's Alpha if Item Deleted
1	2.89	.751	26	.921
2	2.74	.984	26	.918
3	2.93	1.035	26	.901
4	3.00	1.000	26	.902
5	3.15	1.064	26	.905
6	2.56	0.934	26	.909
7	2.81	1.272	26	.912
8	2.96	0.980	26	.915
Dialogue Subscale (α = 0.973)				
Survey Item	Mean	Standard Deviation	N	Chronbach's Alpha if Item Deleted
1	2.33	1.209	26	.976
2	2.96	1.160	26	.971
3	3.33	1.109	26	.970
4	3.37	1.079	26	.969
5	2.96	1.091	26	.971
6	3.22	1.219	26	.969
7	3.67	1.074	26	.970
8	3.19	1.111	26	.970
9	3.37	1.115	26	.968
10	3.19	1.178	26	.970
11	3.26	1.023	26	.971
12	3.30	1.235	26	.972
13	3.26	1.289	26	.971
Participation Subscale (α = 0.946)				
Survey Item	Mean	Standard Deviation	N	Chronbach's Alpha if Item Deleted
1	2.63	1.245	26	.944
2	2.89	1.311	26	.936
3	3.04	1.285	26	.935
4	3.11	1.251	26	.946
5	2.56	1.340	26	.938
6	2.44	1.281	26	.937
7	3.33	1.038	26	.941
8	3.00	1.109	26	.940
9	2.19	1.178	26	.941

Table 3 Continued				
10	2.33	1.359	26	.949
Primary Source Expertise Subscale (α = 0.925)				
Survey Item	Mean	Standard Deviation	N	Chronbach's Alpha if Item Deleted
1	2.67	1.240	26	.916
2	3.89	1.251	26	.921
3	2.59	1.309	26	.896
4	3.04	1.372	26	.897
5	3.37	1.471	26	.908
Interactional Expertise Subscale (α = 0.817)				
Survey Item	Mean	Standard Deviation	N	Chronbach's Alpha if Item Deleted
1	3.15	1.134	26	.793
2	3.44	1.281	26	.751
3	2.56	1.155	26	.804
4	2.81	1.075	26	.759
5	2.63	1.043	26	.795
Contributory Expertise Subscale (α = 0.924)				
Survey Item	Mean	Standard Deviation	N	Chronbach's Alpha if Item Deleted
1	3.78	1.219	26	.916
2	3.07	1.238	26	.891
3	2.59	1.366	26	.900
4	2.85	1.199	26	.909
5	2.44	1.219	26	.918

Descriptive statistics

For communication, the dialogue model was the most widely used (n = 16), followed by the diffusion model (n = 6), and the participation model (n = 4). For perceptions of stakeholder expertise, most participants assumed their stakeholder partner to have primary source expertise (n = 12), followed by contributory (n = 8), and interactional (n = 6). Participants who used the dialogue model of science communication varied in their perception of stakeholder expertise. All participants who used the diffusion model of science communication perceived their selected stakeholder partner to have primary source expertise. Out of the four researchers who used the participation model of science communication, three of them perceived their selected stakeholder to have contributory expertise, while one assumed an interactional level of expertise. See the figure below for a visual representation of the data.

Figure 1
Visual Representation of Data

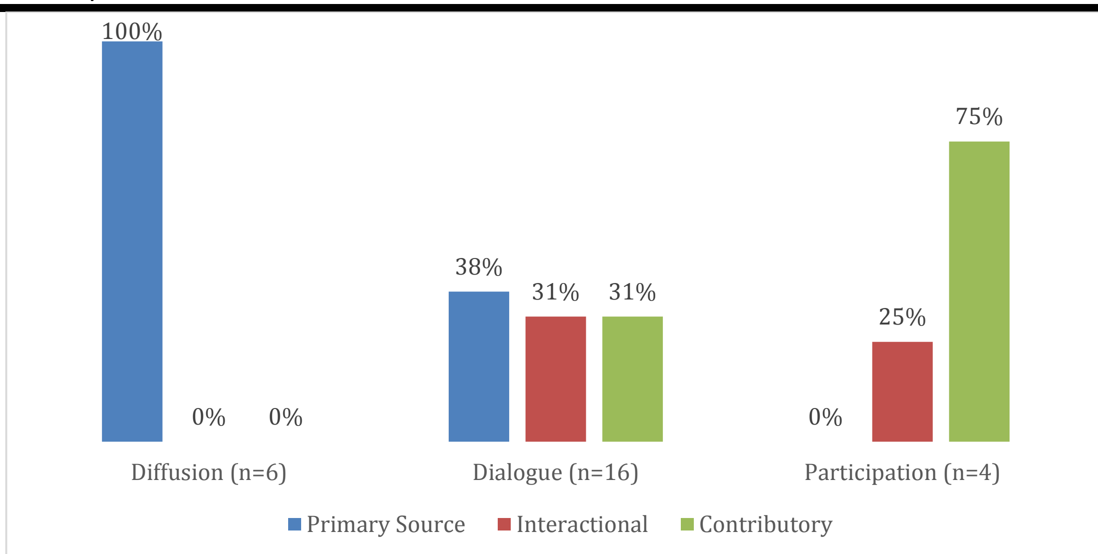

Figure 1

Spearman rank order correlation

A Spearman Rank Order Correlation was run to determine the statistical strength of the relationship between the 26 participants' perceptions of stakeholder expertise and science communication model use. A two-tailed test of significance indicated that there was a strong positive relationship between perceived levels of expertise and higher levels of communication ($r_s = 0.639$, $p < 0.001$). That is, the higher perceived level of stakeholder expertise, the more likely a researcher was to engage in interaction-heavy models of communication. Assuming every participant considers themselves contributory experts in their particular field, the more a participant perceived their selected stakeholder partner to have expertise similar to their own, the more likely they were to use interaction-heavy models of communication (i.e. dialogue and participation).

Discussion

The results of this study indicate a positive relationship between how NEST researchers perceive the expertise level of their stakeholder partners and the manner in which they engage those partners. From a science communication perspective, this work suggests the potential role perceptions of expertise play in the emergence of particular models of science communication. Notably, this relationship was not perfect, and participants who used the dialogue model most often had varying perceptions of stakeholder expertise. This variability could be due to the study context, as NEST researches are encouraged to follow a sustainability science model and move beyond models of information transfer, increasingly the likelihood that they will engage in dialogue with various partners. Importantly, this work only demonstrates a relationship between which communication model a researcher uses *most often* and their perception of stakeholder expertise, which could function to oversimplify the relationship between these two phenomenon. In reality, communication behavior and perceptions of expertise perceptions are far more varied and complex, particularly within sustainability science (see Chapter 2 of this dissertation). Even so, the presence of a statistically significant relationship indicates the need for further work in this arena.

In addition to supporting the role of expertise in science communication research, this work has significant implications for sustainability science. Participatory modes of stakeholder engagement (like the participation model in science communication) are particularly popular within sustainability science in an effort to incorporate the diverse needs, perspectives, and knowledges that are necessary for effective problem solving. This works echoes other work on engagement within sustainability science (e.g. Hutchins, Lindenfeld, Bell, Leahy, & Silka, 2013) in that it highlights the important role of a variety of engagement models. However, the positive relationship between perceptions of expertise and engagement underscores a potential problem in the diversity of engagement in sustainability science: perceptions of expertise could function to exclude some individuals and groups from participatory modes of engagement, particularly if those people are not viewed as interactional or contributory experts. This dynamic, in turn, could impact the level at which sustainable solutions garner buy-in from various publics. As such, the results of this study suggest that perceptions of stakeholder expertise should be explicitly discussed within sustainability science teams, and careful consideration should be given to how and why different stakeholder groups are being engaged, and the extent to which different modes of engagement foster an effective environment for the co-production of knowledge.

Limitations and directions for future research

There are three key limitations to note. First, the sample size for this study was small so results cannot be generalized outside of the NEST Safe Beaches and Shellfish Project. While some theoretical work has examined the various levels of expertise embedded within each science communication model (e.g. Hetland, 2014), much more work is needed in a variety of different science communication contexts to establish this connection outside of the specific context for this study. Second and relatedly, these results only suggest a correlational relationship and do not support claims of causality. Though theoretically perceptions of expertise would precede science communication behavior, more work is needed in order to empirically investigate the strength of the causal relationship between the two concepts. Third, the scales that were developed for this study used qualitative data within a particular sustainability science context, and are likely only applicable within the NEST Safe Beaches and Shellfish Project. Despite the high levels of internal consistency reported above, these survey items should not be taken as an attempt at scale development.

Owing to these limitations, this work highlights four key areas for future research. First, future work ought to examine expertise as a relevant variable in science communication in different contexts in an effort to explore the extent to which this relationship remains statistically significant. The vast variability of science communication practice (Nisbet & Scheufele, 2009) provides a rich source of diversity within which to study these dynamics. Second, future work ought to pair the study of expertise and science communication behavior with communication satisfaction data or evaluations of communication outcomes in an effort to evaluate the extent to which perceptions of expertise and subsequent communication behavior relate to the relative effectiveness of science communication efforts. Third, there is an opportunity to study perceptions of expertise and communication preferences nonscientific audiences, to explore the extent to which perceptions of expertise impacts communication preferences. Fourth, there is an opportunity to study these variables on a larger scale in an effort to develop predictive models and get a better understanding of the causal relationship between perceptions of expertise and science communication behavior.

CONCLUSION

Dissertation summary

This dissertation demonstrates the value in exploring epistemological beliefs within science communication research, particularly within sustainability science. Through this work, we can begin to understand when and why different science communication models emerge and, eventually, when they ought to emerge. Chapter one presented key factors that support the persistence of the deficit model in science communication research and practice: the purpose of science communication, how science communicators conceptualize communication, and how science communicators understand science and scientific knowledge. I focused exclusively on the relationship between affording science epistemic privilege, perceptions of expertise, and science communication practice in this dissertation. However, there is a key opportunity to explore the overall ethos of science communication and conceptualizations of communication in future work. While chapter one argues for the role of these factors in the continued use of the deficit model, these factors could relate to the use of other models (e.g. dialogue, participation) as well.

This work allows us to begin to understand the relationship between epistemic assumptions and science communication practice. Chapter two explored NEST researchers' perspectives on the epistemic authority of science and their science communication behavior. Specifically, this work exposed an implicit contradiction facing scientific researchers who aim to mobilize participatory models of engagement and integrate multiple epistemologies in the formation of sustainable solutions. Chapter three explored the statistical relationship between science communication model use and perceptions of stakeholder expertise. While this work cannot demonstrate a causal relationship between these concepts, it does support the utility of future work in this arena.

Finally, this work demonstrates how science communication research can inform sustainability science more broadly. In practice, science communication theory can aid in organizing and systematizing stakeholder engagement activities and preferences for both researchers and stakeholder partners. Trench's (2008) analytical framework for science communication, while not specifically employed here, could be particularly useful in this endeavor. If employed to systematize stakeholder engagement, a science communication framework could also allow for the examination of when particular models of engagement are effective and when they are not. This kind of work could include identifying other variables (like expertise) that relate to engagement and could be used as proxies to understand and improve stakeholder communication.

In theory, this work allows for a critical examination of how epistemic assumptions relate to the capacity for sustainability science researchers to meaningfully engage in participatory models of engagement, insofar as this engagement requires the integration of different epistemologies within the research process. While the data presented here does not indicate affording science epistemic privilege impedes meaningful engagement, it does demonstrate a conceptual conundrum facing sustainability science: is it realistic to expect scientific researchers who consume, evaluate, and produce knowledge in very specific ways to meaningfully integrate nonscientific perspectives within the context of their work, and is this processes necessary for creating sustainable solutions?

Limitations

This research is limited in four key ways. First, it only focuses on one sustainability science team in New England. While chapter one addresses the concepts explored in this dissertation much more broadly, the data collected and represented here can only speak to these concepts within the context of the New England Sustainability Consortium's Safe Beaches and Shellfish Project. Second, this work does not quantify epistemic beliefs (the concept explored in chapter two), but rather uses expertise as a proxy for epistemic authority. This proxy was chosen given the reluctance of NEST researchers to explicitly assert the authority of science during the interview phase of this work. Rather than rely on self-report regarding epistemic authority within a survey, then, I chose to examine stakeholder expertise as it related to the participants' particular expertise level (insofar as researchers can be considered contributory experts). While not a perfect substitution, these concepts are arguably related. If a NEST researcher views science as the best method for knowledge production, assessing the extent to which they believe their stakeholder partners are capable of consuming, conversing, and producing scientific knowledge does serve as a useful proxy.

Third, this work only assesses a correlational relationship between the communication model a participant used *most often* and their perception of stakeholder expertise. Because every participant used at least two of the models to some extent, the relationship between the two concepts is likely much more nuanced and complex than the correlational results presented here might suggest. Fourth and finally, this work treats the participation model of science communication as somewhat identical to the participative model of engagement in sustainability science. While they mirror each other in their epistemic goals (i.e. fostering a more egalitarian epistemic environment) and communication structure (i.e. a continuous integration of diverse perspectives), it is possible they differ in ways that make their direct comparison here slightly erroneous.

Future work

This dissertation highlights key areas for future research. First, as overviewed in chapter one, it is critical that science communication scholars engage in a critical examination of the field's purpose, the nature of communication, and the nature of science itself. These theoretical discussions are particularly appropriate given the youth of science communication as field of study, as these kinds of discussions stand to clarify, unify, and improve science communication as an academic endeavor. Second, this dissertation highlights the potential connection between epistemic assumptions (studied here through the concepts of epistemic authority and expertise) and the use of science communication models. Future work ought to examine these relationships on a much broader scale, and attempt to isolate a causal connection between them in a variety of contexts both within and outside of sustainability science. Future work in this arena should include efforts to illuminate the relationship between philosophical assumptions about science more broadly (e.g. epistemology, ontology, axiology) and engagement behavior. Finally, there is a key opportunity to conduct similar work with nonscientific stakeholder groups to examine stakeholders' perception of epistemic privilege and science communication preferences. This work is particularly appropriate given that implicit disagreement between researchers and stakeholders regarding the role (actual or desired) of science in decision-making could significantly impact collaborative outcomes. Understanding these dynamics is essential, particularly within sustainability science where merging various epistemologies is required.

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APPENDIX A: INTERVIEW PROTOCOL

Identity & Perceptions of Science

1. What is your role in NEST? Do you see yourself as part of any teams or sub-teams, and if so, which ones?

2. What is your area of expertise? How would you describe your work?
    a. If not mentioned: what kind(s) of methods do you use (experimental, observational, etc.)
    b. Would you characterize your work as basic or applied?
    c. Does your work change when it is part of large project like NEST? If so, how?

3. What does interdisciplinarity mean to you? How about integration?
    a. How would you characterize the interdisciplinary collaboration within NEST?
    b. Are you collaborating with people in other disciplines? If so, how is that going?
    c. What do you consider effective communication in a team like NEST? Do you enact that yourself and, if so, how?

4. What do you see as the *value* in doing scientific research?

5. Do you think scientific knowledge differs from other types of knowledge? If so, how?

Stakeholder Communication

6. What stakeholders have you communicated with the most throughout this project? (Limit to 5 individuals)
    a. Tell me a little bit about that communication; does an example come to mind?

7. What do you see as *the purpose* of communicating with stakeholders? What outcomes are you hoping for?

    a. What do you consider effective communication with stakeholders (i.e. how do you know you are communicating effectively)?

b. Has communicating with stakeholders been a positive experience for you? If so, how? If not, why not?

8. Thinking back about your experience communicating with stakeholders about your work, what are some communication strategies that worked well? What hasn't worked as well? Lessons learned?

Repeated Questions from Previous Protocol

9. What do you see as the major outcomes of this project? *How has this changed over the course of the project?*

    a. What will success look like?

    b. What would you consider failure?

    c. Where do you think we are in the project in terms of outcomes?

10. Overall, how would you characterize the decision making on NEST?
    a. Within the leadership team? Within your research team(s)/sub-team(s)?
    b. What parts of the decision making on NEST are working for you?
    c. Are there aspects of the decision making would you change you could?

11. How does the collaboration on this project compare to your experience on your Track I? Is it easier, more challenging, about the same? Why do you think that is?

Follow Up Question

12. Has your experienced on the project matched with your expectations? If so, how? If not, why not?

APPENDIX B: SURVEY PROTOCOL

Thank you for taking the time to complete this survey!

Before you begin, think about the stakeholders you have communicated with throughout the course of your academic work, either on NEST or another project. These individuals could include, for example, policy makers, government officials, fishermen, beach managers, members of a shellfish committee, tribal members, business professionals, members of a non-profit organization, beach users, etc.

Choose ONE of these individuals, and answer all of the questions in this section with them in mind.

Please indicate the name, occupation and organization (if applicable) of this stakeholder (e.g. "John Smith, Executive Director, the Environmental Protection Agency"). ***If you'd prefer to keep the stakeholder anonymous, simply type 'anonymous' in the 'name' field.***

Name:
Occupation:
Organization (if applicable):

Please indicate how often you communicate with this stakeholder for the following reasons.

	Never	Rarely	Sometimes	Often	Almost Always
To provide them with information about the grant project	☐	☐	☐	☐	☐
To help them understand and interpret research results	☐	☐	☐	☐	☐
To make sure there is an outlet for research	☐	☐	☐	☐	☐
To give them scientific information	☐	☐	☐	☐	☐
To obtain their feedback	☐	☐	☐	☐	☐

on the research process (e.g. crafting research questions, selecting research sites, etc.)					
To understand their research needs	☐	☐	☐	☐	☐
To actively involve them in my own research project(s) (e.g. collecting or analyzing data)	☐	☐	☐	☐	☐
To listen to them to identify directions for future research	☐	☐	☐	☐	☐
To produce knowledge with them	☐	☐	☐	☐	☐
To obtain their feedback on desired research outcomes (e.g. decision-support tools)	☐	☐	☐	☐	☐
To tell them about the work that's being done on the grant	☐	☐	☐	☐	☐
To combine their expertise with my own to improve research outcomes	☐	☐	☐	☐	☐
To provide them with information about my research or the research of my colleagues	☐	☐	☐	☐	☐
To convey a particular message about the social or biophysical environment	☐	☐	☐	☐	☐
To understand how my	☐	☐	☐	☐	☐

work can be most helpful to them					
To understand their perspective	☐	☐	☐	☐	☐
To experience what it's like to live in their world	☐	☐	☐	☐	☐
To provide them with research results	☐	☐	☐	☐	☐
To work with them on a research project	☐	☐	☐	☐	☐
To design and execute research projects with them	☐	☐	☐	☐	☐
To provide an opportunity for us to learn from each other	☐	☐	☐	☐	☐
To combine their expertise with my own to improve the research process	☐	☐	☐	☐	☐
To work with them in conducting their own research project(s)	☐	☐	☐	☐	☐
To better understand the nature of the research problem(s) from their perspective	☐	☐	☐	☐	☐
To understand their needs	☐	☐	☐	☐	☐
To understand their expectations	☐	☐	☐	☐	☐
To build a resilient relationship with them	☐	☐	☐	☐	☐

To establish rapport, trust and/or respect with them	☐	☐	☐	☐	☐
To understand the work that they do	☐	☐	☐	☐	☐
To work with them in doing research (i.e. citizen science)	☐	☐	☐	☐	☐

Please indicate the extent to which you agree with the following statements about where this stakeholder learns about YOUR area of expertise.

"This stakeholder learns about my area of expertise primarily..."

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
through popular culture	☐	☐	☐	☐	☐
by reading newspapers or television	☐	☐	☐	☐	☐
through mass media	☐	☐	☐	☐	☐
from popular books	☐	☐	☐	☐	☐
through social media	☐	☐	☐	☐	☐
from reading journal articles in my field	☐	☐	☐	☐	☐
from talking with experts in my field, including myself	☐	☐	☐	☐	☐
from reviewing scientific literature in my field	☐	☐	☐	☐	☐
from reading scientific and/or technical reports	☐	☐	☐	☐	☐

from attending conferences	☐	☐	☐	☐	☐

Please indicate the extent to which you agree with the following statements about this stakeholder.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
In my experience, this stakeholder is able to use my disciplinary jargon effectively	☐	☐	☐	☐	☐
This stakeholder has enough practical competency in my field that they can meaningfully contribute to my research	☐	☐	☐	☐	☐
This stakeholder has done research in my field, or related field(s), in the past	☐	☐	☐	☐	☐
I can communicate with this stakeholder about my work without worrying about being too technical or using too much jargon	☐	☐	☐	☐	☐
This stakeholder knows enough about my area of expertise to do research in my field	☐	☐	☐	☐	☐
This stakeholder is able to use my disciplinary jargon effectively (i.e. “talk the talk”), but they don’t know enough to pragmatically contribute to my field (i.e. “walk the walk”)	☐	☐	☐	☐	☐

This stakeholder knows enough about my area of expertise to talk about it, but not enough to do research in the area themselves	☐	☐	☐	☐	☐
This stakeholder is able to inform my research process as adequately as the colleagues in my field (e.g. research design, crafting research questions, collecting data, etc.)	☐	☐	☐	☐	☐
This stakeholder knows enough about my area of expertise to talk about it using my discipline's jargon, but not enough to do research in my field.	☐	☐	☐	☐	☐
This stakeholder has enough practical competency in my field to do the research by themselves	☐	☐	☐	☐	☐
This stakeholder only knows as much about my area of expertise as you could learn from popular culture (e.g. movies, television, books, etc.)	☐	☐	☐	☐	☐
This stakeholder knows as much about my area of expertise as you could learn from reading literature in my field	☐	☐	☐	☐	☐
This stakeholder knows as much about my area of expertise as you could learn	☐	☐	☐	☐	☐

from doing research in my field	

In this section, we are interested in your motivations to engage with stakeholders <u>more generally</u>. Please indicate the extent to which you agree with the following statements.

"I am motivated to engage with stakeholders in the NEST project because..."

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
they will help me be the kind of scholar I want to be	☐	☐	☐	☐	☐
of the funding this project provides	☐	☐	☐	☐	☐
this project requires me to include them	☐	☐	☐	☐	☐
I really enjoy working with stakeholders	☐	☐	☐	☐	☐
I don't have the right to exclude stakeholders from processes that may impact them	☐	☐	☐	☐	☐
I feel like I've failed if my research isn't used by society	☐	☐	☐	☐	☐
it will help me educate and train citizens, a central goal in my work	☐	☐	☐	☐	☐
it makes my research relevant and socially appropriate	☐	☐	☐	☐	☐

my colleagues brought them into the process	☐	☐	☐	☐	☐
of the satisfaction I experience from taking on interesting challenges	☐	☐	☐	☐	☐
I want to help empower stakeholders to have a voice in the research	☐	☐	☐	☐	☐
I want to be recognized by my peers as doing this work well	☐	☐	☐	☐	☐
the partnership(s) help ensure stakeholders' and researchers' needs are met	☐	☐	☐	☐	☐
it helps me bring on more graduate students	☐	☐	☐	☐	☐
my department required my participation	☐	☐	☐	☐	☐
I enjoy learning from people with different types of knowledge	☐	☐	☐	☐	☐
I believe the issue I study is in a state of crisis	☐	☐	☐	☐	☐
it will help ensure the sustainability of the issue(s)/resource I study / care about	☐	☐	☐	☐	☐
I have nothing to lose	☐	☐	☐	☐	☐
their involvement in this research is more likely to influence individual and/or institutional action	☐	☐	☐	☐	☐
it will help resolve conflict among	☐	☐	☐	☐	☐

stakeholders					
stakeholders leverage additional financial resources for the project	☐	☐	☐	☐	☐
stakeholders provide access to additional personnel, including volunteers	☐	☐	☐	☐	☐
stakeholders help connect core team members to other social networks	☐	☐	☐	☐	☐
I want them to see me, my colleagues and/or my institution as a resource for them	☐	☐	☐	☐	☐
I want them to see me, my colleagues and/or my institution in a positive light	☐	☐	☐	☐	☐
Other (please specify): ______________________________	☐	☐	☐	☐	☐

Where have you learned the knowledge and skills that help you communicate with stakeholders? Select ALL that apply

- ☐ Formal graduate / professional school coursework or training
- ☐ Faculty / researcher mentoring during graduate school
- ☐ Colleague mentoring during research projects
- ☐ Formal training through an employer
- ☐ Conference workshops or online training (e.g. webinars)
- ☐ On your own through reading and/or observing others skilled in this area
- ☐ Not applicable - I do not have knowledge and skills in this area
- ☐ Not applicable - I do not have knowledge and skills in this area and am not interested in learning them
- ☐ Other (please specify):☐ ____

In general, how satisfied are you with <u>your</u> stakeholder communication?

Not at all Satisfied	Slightly Satisfied	Moderately Satisfied	Very Satisfied	Extremely Satisfied
☐	☐	☐	☐	☐

Please explain:
____

In general, how satisfied are you with the stakeholder communication on <u>the NEST project as a whole</u>?

Not at all Satisfied	Slightly Satisfied	Moderately Satisfied	Very Satisfied	Extremely Satisfied
☐	☐	☐	☐	☐

Please explain:
____

Please use the box below to enter any additional comments you would like to share to help us understand your stakeholder communication experience(s).

____

Please select your institutional affiliation:

- The University of Maine
- The University of New Hampshire
- Affiliate College or University
- Government Agency
- Non-profit Organization
- Other (please specify): ________________________

Please select your position(s) within your institution:

- o Director or other upper administrative position
- o Assistant Professor
- o Associate Professor
- o Full Professor
- o Masters Student
- o Ph.D. Student or Candidate
- o Post-Doctoral Fellow
- o Professional Staff
- o Other (please specify): ________________________

Please indicate your area of expertise:

- o Administrative
- o Biophysical Sciences
- o Engineering
- o Fine Arts or Humanities
- o Social Sciences
- o Other (please specify): ________________________

Please list the NEST team(s) / sub-team(s) you are a part of (e.g. social, biophysical, coastwide, etc.)

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BIOGRAPHY OF THE AUTHOR

Brianne Suldovsky was born in Bonners Ferry, Idaho on November 20, 1987. She graduated from Bonners Ferry High School in 2006, and attended the University of Idaho from 2006-2010 where she graduated with a Bachelors' degree in communication, a Bachelor's degree in philosophy, and a minor in religious studies. She completed her Master's degree in communication at Washington State University in 2012. She then moved to Maine in 2012 to pursue her doctoral degree in communication. After receiving her degree, Brianne will be joining the Annenberg Public Policy Center at the University of Pennsylvania as a science of science communication postdoctoral fellow. She is a candidate for the Doctor of Philosophy degree in Communication from the University of Maine in May 2016.