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Doing broader impacts? the National Science Foundation (NSF) broader impacts criterion and communication-based activities

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ABSTRACT

This study examines broader impact activities that are used to fulfill National Science Foundation's (NSF) broader impact criterion (BIC). While there have been many studies that discuss the merits and pitfalls of asking scientists to address BIC, there have been few studies that examine exactly what types of outreach and science communication activities Principal Investigators (PIs) are proposing to do. In an effort to fill this gap, this thesis draws from science communication theory and program logic modeling to inform a qualitative analysis of proposed broader impacts activities (BIAs) in NSF grant proposals. Through an analysis of 87 proposals, this thesis explore the types of activities proposed, audiences reached, and their relation to the PUS and PEST models of science communication. The results suggest that PIs mainly propose academic-related activities that are intrinsic to their duties as university faculty members. Although rare, when PIs do engage with the public they choose activities that fall into the PUS-style of science communication.

KEYWORDS: Broader Impacts, BIC, science communication, public outreach for science

CHAPTER 1

INTRODUCTION AND STATEMENT OF THE PROBLEM

Many of the major issues facing society today contain a science or technical component. Scientifically thrust national issues such as biotechnology, stem-cell research, climate change, and childhood vaccinations all require informed citizens to weigh in. In order for individuals to be able to enter the discussion and make educated decisions about the issue at hand, they need access to scientific information. Science communication attempts to fill this societal need.

Science communication at its core seeks to impart information for three reasons: "prevention of knowledge deprivation," education, and promotion (Van der Sanden & Meijman, 2002, 1). "Prevention of knowledge deprivation" refers to informing the audience of the facts they *ought to know*, such as instructions. Education refers to the actual scientific facts that are passed along and promotion relates to informing people about the processes and products of science to better understand the impacts. These three principles of science outreach are not just academic aspirations; they have been tied to larger scientific processes, namely, funding.

Since its inception, the United States' National Science Foundation (NSF) has been closely tied to societal goals. Created by an act of Congress in 1950, the federal organization works "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense" (National Science Foundation Act, 1950, para. 1). The NSF, which accounts for almost a quarter of the federal support for basic research in higher education institutions (National Science Board, 2012), has incorporated these larger outreach principles into its grant funding process. The organization now requires that Principal Investigators (PIs), the person primarily responsible for the research project, not only defend the technical merits of their research but also address the project's larger scientific and societal value under the Broader Impacts Criterion (BIC). In essence, BIC is one massive science communication and outreach exercise carried out by NSF, with each grant contributing to the BIC goals. Having many incarnations over the years, BIC comprises five core long-term outcomes: teaching and education, broadening participation of underrepresented groups, enhancing infrastructure, public dissemination, and other benefits to society.

The push towards addressing societal needs has been met with "considerable confusion and dread" (Lok, 2010) by PIs. PIs have argued that the criterion is neither transparent nor practical (Bornman, 2013). Further research suggests there are deeper reasons for not wanting to address BIC: PIs are adverse to BIC because of lack of individual efficacy in answering and fulfilling the criterion, lack of desire or interest to engage, and even the belief it is not within their duties to do science communication and outreach (Bozeman & Boardman, 2009; Alpert, 2009; Nagy, 2013; Holbrook & Frodeman, 2011). Regardless of NSF's work towards explaining BIC, the criterion remains cloudy.

One way to help clarify the program is to examine the specific activities researchers are proposing to meet the broad goals and develop a framework toward a more pragmatic understanding of addressing BICs. In short, when posed with the requirement to fulfill the BIC, what are researchers proposing to do? In an effort to answer this question, this thesis draws from science communication theory and program logic modeling to inform a qualitative analysis of proposed broader impacts activities (BIAs) in NSF grant proposals.

Significantly, this thesis employs program logic modeling as a new way for PIs to conceptualize BIC. By recognizing BIC as long-term goals, or BIC outcomes, the burden to address societal needs with a single grant proposal can be alleviated. Instead, PIs can focus on BIAs, small-scale interventions that share, teach, promote, or communicate, or otherwise engage an audience in the processes and products of science and research. PIs can then understand their proposed BIAs as *contributing to* as opposed to *being responsible for* achieving long-term BIC outcomes. This thesis works to alleviate some of the confusion about addressing BIC and to provide PIs with a framework of types of BIAs that can be used to address BIC outcomes. Likewise, because public dissemination is one of the broad BIC outcomes and necessary to allow the public to make informed decisions about science and technical issues in society, yet one with which researchers may be least comfortable, this thesis also examines what types of public dissemination activities are proposed and how they align with models of science communication.

The original contribution of this work lies in three areas. First, this thesis reorients broader impact research away from the broadly-stated NSF BIC outcomes towards BIAs. Second, whereas other studies have chosen their abstract samples based on NSF program area (Nadkarni & Stasch, 2012) or NSF directorate (Roberts, 2009; Kamentsky, 2011), the data set employed here comprises full proposals from a single large Midwestern land-grant university. This provides both an alternative way to understand and assess BIC and a practical starting point for those at a university-level who are seeking new ways to invigorate science communication and outreach. Aggregating BIAs at the university level provides both a better idea of the preferences of researchers at a single institution and an opportunity to identify strengths as well as opportunities for improvement, growth, collaboration, and expansion. Third, this thesis further dissects activities related to public dissemination to assess how researchers conceptualize this outcome and under which model of science communication they are formed. In sum, this thesis will speak to two audiences: PIs hoping to better understand and work through writing broader impacts sections and science communicators and outreach specialists who want to track the trends, preferences, and state of current BIAs as they relate to academia and the public.

To lay out the organization of this thesis, Chapter 2 comprises a discussion of science communication models, a background of broader impacts at NSF, previous BIC studies, and an overview of program logic modeling. The chapter concludes with a statement of the research questions. Chapter 3 lays out the methodology and data set employed in this study. Chapter 4 relays the findings. Chapter 5 provides a discussion of the findings, limitations, and areas for further research.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

This thesis explores the BIAs that are used to fulfill NSF's BIC outcomes. This chapter first describes the dominant models of science communication underlying the analysis and then provides a history of the incorporation of BIC in NSF. The chapter then moves on to discuss previous BIC studies and the utility of program logic modeling as a conceptual tool to reorient broader impacts research towards more pragmatic categorization. The chapter ends with the research objectives of this project.

2.1 Models of Science Communication

The two main models describing the role of science communication within society, Public Understanding of Science (PUS) and Public Engagement of Science and Technology (PEST), are based on different understandings of the needs and aptitudes of the audience. Public Understanding of Science (PUS) is a diffusion model (Horst & Michael, 2011), where scientific information is transmitted to an information-poor public. This model rests on two assumptions. First, that ignorance is the source of the problem (Nisbet & Scheufele, 2009). Second, if that knowledge deficit is filled through the relying of facts from scientists to the lay public, then this leads not only to an understanding but also an implicit acceptance of science (Miller, 2001). To offer an example, in recent years there has been considerable public debate about the safety and dangers of genetically modified foods (for example, see Rosenthal, 2007; Levaux, 2012; Bittman, 2012; Catsoulis, 2013; Castle, 2014). A scientist working from the PUS perspective might think the problem is that the public is not educated about the research and science behind genetically modified organisms (GMOs). Once informed, however, the public will both have a better grasp of the debate and be more accepting of GMOs.

This theory of the direct transmission of information from scientists to the public has been problematized by many. The prioritization of scientific knowledge over other epistemological channels led many scholars to question the purity of the sender-receiver model (Schäfer, 2009). Science popularization studies argued that knowledge is not transmitted in its entirety, but instead its meaning is negotiated by the audience (Miller, 2001; Hilgartner, 1990). From these critiques of the PUS model emerged a more nuanced understanding of the public's role in knowledge creation and acquisition, leading to the PEST model.

The PEST model emphasizes two-way transmission between science and the public, where information is presented in formats stimulating input from or facilitating discussion with the public (Irwin, 1995; Wynne, 1995). Under this model, science communication means "science engagement" and includes events such as forums, dialogues, and citizen panels. For instance, the Science Café movement exemplifies the PEST model. At Science Cafés scientists meet with the public in a casual space, usually a bar or coffee shop. There "the lay audience and the speaker are considered equals and the agenda is not education; rather, the audience is encouraged to question scientists about their motives, funding, and career structure. They are perhaps the scientific equivalent of book clubs" (Russell, 2010, p. 93). PEST not only prompts a more nuanced approach to understanding the public, it also turned a critical eye towards the institutions of science. The knowledge deficit shifted from being part of the public's profile to that of the research community's, who was seen by some as neither adept at nor attentive to addressing public concerns (Bauer, Allum, & Miller, 2007; Wynne, 2006). But the PEST model also did not escape criticism. Many saw the PEST model as a thinly-veneered PUS model because dialogue was taking place too far downstream for it to have much impact (Bubela et al., 2009).

It is not difficult to see the parallels between the science communication discourse and the mid-twentieth century discourse in mass communication studies, wherein the dominant "injection needle" model characterized by a passive public and an authoritative sender was problematized by those who argued for a more nuanced conceptualization of a varied and active public and the construction of knowledge between groups (McQuail, 2010). As Brian Trench (2006) has written, "it is perhaps inevitable that a relatively new field of inquiry and practice, such as science communication, needs to rerun such debates for itself" (p. 119).

Regardless of the theoretical bifurcation between the PUS and PEST models, in practice the heavy lines are blurred. Bucchi (2008) holds that examining individual science communication initiatives based on various dimensions might be more productive than attempting to champion either PUS or PEST. Brossard and Lewenstein (2010) make a similar argument, noting that in practice science communication activities often incorporate elements from both models.

While many scholars of science communication have debated these models, many scientists have not. In practice, scientists continue to view communication with the public as difficult and dangerous. Davies (2008) found in interviews with scientists that "negativity toward communication is a key theme within the data, even when public communication is itself seems as a worthwhile thing to do" (p. 421). Further research suggests that scientists continue to view that the public is uninformed about science (Besley & Nisbet, 2013). As such, scientists often conceptualize science communication from a PUS model perspective, believing that the issue can be fixed with a greater attentiveness to disseminating just "the facts" (Davies, 2008; Johnson, Ecklund, & Lincoln, 2014). By aligning BIAs with varying degrees of PUS and PEST models of science communication, this thesis provides information about current proposed efforts to communicate with the public, and provides opportunities to assess the strengths and weaknesses of BIAs.

2.2 History of BIC at NSF

Perhaps there has been no greater commitment to science communication and outreach than NSF making broader impacts one of its two merit review criteria for funding. Although BIC has only recently become a major point of debate, NSF has asked researchers to consider the value of their research beyond the lab since the 1960s (Rothenberg, 2010, p. 191). In 1995, proposals were assessed against four merit criteria, with the last two most directly relating to societal benefit. Criterion 3 was "used to assess the likelihood that the research can contribute to the achievement of a goal that is extrinsic or in addition to that of the research field itself, and thereby serve as the basis for new or improved technology or assist in the solution of societal problems" (NSF, 1995, p. 21). Criterion 4 was meant to encompass "effect on the infrastructure of science and engineering" and in an additional note, the guide explained that the criterion

> permits the evaluation of proposals in terms of their potential for improving the

> scientific and engineering enterprise and its education activities in ways other than those encompassed in the first three criteria. Included under this criterion are questions relating to scientific, engineering and education personnel, including participation of women, minorities and individuals with disabilities; the distribution of resources with respect to institutions and geographical area; stimulation of high-quality activities in important but underdeveloped fields; support of research initiation for investigators without previous Federal research support as a principal investigator or co-principal investigator; and interdisciplinary approaches to research or education in appropriate areas (NSF, 1995, p. 22).

However, the guide also noted that the first three criteria (research performance competence, intrinsic merit of research, and utility or relevance of the research) "constitute an integral set and are applied in a balanced way to all research and science education proposals in accordance with the objectives and content of each proposal" (NSF, 1995, p. 21). This caveat implicitly subordinated Criterion 4's importance to the other three. Two years later in 1997, broader impacts transitioned from being a peripheral consideration to becoming a main criterion. The former four criteria were reorganized into the two-criterion system still in place today. It was now compulsory that PIs address how their research would add to their respective field of scientific study under the intellectual merits section and under the broader impacts section PIs explained how their research would positively contribute to society or advance the societal goals emphasized by NSF:

> How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the

> participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society? (NSF, 1997, p. 15).

With subsequent revisions through the late 1990s and 2000s, none of which changed the two criteria format or the overall integrity of broader impacts, the 2010 guidelines asked PIs to address:

- how the project will integrate research and education by advancing discovery and understanding while at the same time promoting teaching, training, and learning
- ways in which the proposed activity will broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)
- how the project will enhance the infrastructure for research and/or education, such as facilities, instrumentation, networks, and partnerships
- how the results of the project will be disseminated broadly to enhance scientific and technological understanding
- potential benefits of the proposed activity to society at large (NSF, 2010)

Because the data used in this study is from 2009 to 2011, it is important to focus on the BIC as articulated during that period. To be sure, since that time NSF has revised its criteria which, in addition to the five points above, now includes improving national security, developing of a STEM workforce, increasing economic competitiveness on a national level, and increasing "public scientific literacy and public engagement with science and technology" (NSF, 2013).

Regardless of the increasing calls for accountability of public monies spent on research (Holbrook, 2005; Holbrook & Frodeman, 2011), implementing this grant procedure has been a struggle for NSF. In the past, PIs have been reluctant to incorporate BIC activities into their proposals (Bozeman & Bordman, 2009) leading to increasing insistence from NSF. Now grant proposal guidelines stipulate that proposals must address separately each merit review criteria or risk having their proposal returned without review (NSF, 2013).

However, "despite the NSF's efforts to educate scientists about broader impacts through websites, workshops and conference sessions, most still approach the criteria with confusion and dread" (Lok, 2010, p. 417). Some scientists have questioned the utility of rerouting time and resources toward activities for which they feel ill-prepared (Alpert, 2009). Others have "asserted that the BIC is simply unanswerable as it is impossible to make meaningful statements about the potential usefulness of basic research" (Nagy, 2013, p. 42). Lok (2010) questioned whether it was a scientist's individual responsibility to address BIC, asking "is the NSF 'passing the buck' by asking scientists to meet what is essentially a political goal: demonstrating the benefits of science?" (p. 418). Bozeman and Boardman (2009) noted that a "compelling reason to abandon the idea that scientists can make valid judgments about social utility is that there is considerable evidence that researchers in most cases have no particular interest in doing so" (p. 190). In sum, reactions to performing broader impacts activities echo the larger hesitations about communicating science to the public discussed in the previous section. Regardless of the philosophical debates, the criterion remains part of the NSF funding requirements. Yet by focusing on the actual activities, this thesis strives to alleviate some of the dread surrounding fulfilling the BIC requirement, thereby increasing scientist efficacy and improving outreach overall.

2.3 Studying BIC

Four major studies examining BIC have been conducted. Roberts (2009) performed the first empirical study of BIC. She framed her study around the ongoing debate about the utility of BIC, asking whether researchers chose to address broader impacts that benefit science or society; whether those who mentioned potential societal benefit are really "use-inspired" or focused on problem solving; and subsequently whether this research promoted greater societal benefit. To code broader impacts, she derived seven different categories from the NSF's broader impacts criterion and subsequently divided them under two headings: "criteria for science" and "criteria for society." Using this framework, she found that "including potential societal benefits of BIC is of limited use for optimizing knowledge flow, and ultimately societal benefit" (p. 213), citing missed opportunities for broad dissemination as one of the main culprits. Kamenetzky (2013), heavily relying on Roberts' framework, empirically examined grant award abstracts for differences within different fields funded under NSF and representation of women. She concluded there was no statistical difference between PIs of either gender within fields (p. 83).

As opposed to drawing a data set of proposal abstracts from across various NSF directorates, Nadkarni and Stasch (2012) instead focused their study entirely on one discipline area - NSF's ecosystems studies program. They also researched the size and type of audience that would be reached, what type of communication would be used to reach the proposed audience, and the distant from academia of the proposed audience, again using the five BIC criteria. The study found that students dominated the intended audience. An additional study commissioned by NSF itself is also worth mentioning. As part of the National Science Board's review of the NSF merit criteria in 2011, a topic model was applied to assessing broader impacts in grant proposals. An algorithm was used to isolate and generate a list of relevant topics (which are not included in the publication) and were then combined under their respective broader impacts categories. Of the approximately 100,000 proposals scanned, the vast majority focused on teaching, training, and learning, findings corroborated by the smaller studies summarized above.

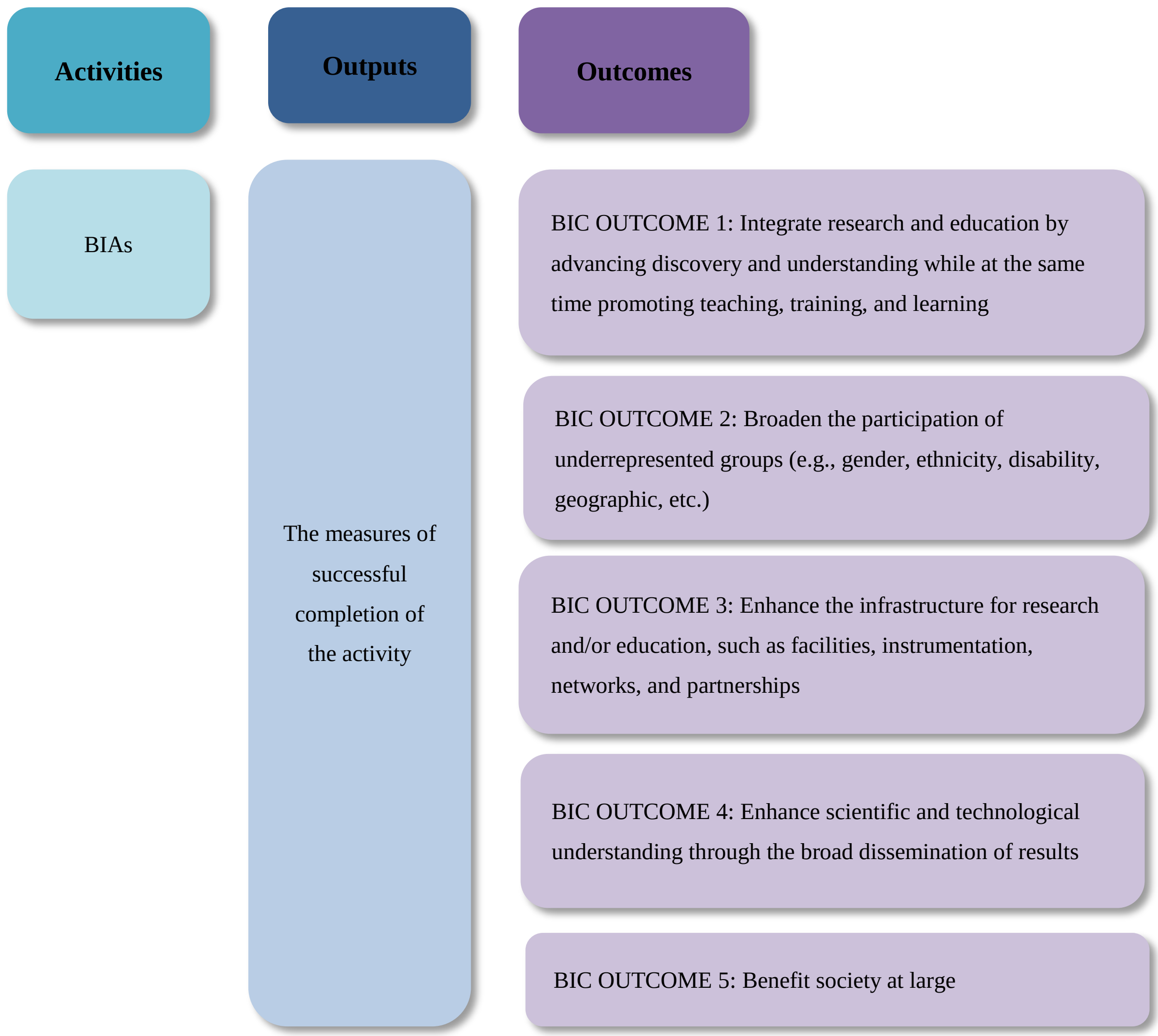
The previous studies used the five BIC outcomes (teaching and education, participation of underrepresented groups, enhancing infrastructure, broad dissemination, other potential benefits) as the main coding categories. These five broader impacts criteria encapsulate the long-term goals of the NSF. In the end, what can be gleaned from using broader impacts criteria as assessment categories is only which categories are preferred by researchers. They do not operationalize specific types of activities that researchers could, should, or might propose to fulfill these larger goals. For example, coding for the BIC "broadening the participation of underrepresented groups" does not indicate how many members of an underrepresented group will be involved; whether the activity takes place in the lab, in the classroom, or in a larger public arena; or whether the project is focused on mentoring select students or initiating community-wide involvement. Each of these activities would take different resources, planning, and has different levels and types of societal impact, regardless of all being included under "underrepresented groups." Therefore, parsing out broader impact criteria categories into planned activities is imperative to gaining a deeper understanding of what is actually happening on the ground. To begin an investigation of proposed activities, program logic modeling is a solid starting point.

2.4 Program Logic Modeling

This thesis employs program logical modeling as a conceptual tool to organize BIC. Program logic models are "visual representations of the structure of programs that describe and explain the intended cause-and-effect linkages connecting resources, activities, and results" (McDavid, Huse, & Hawthorn, 2013). The approach separates broader impacts goals, or outcomes, with the actual activities researchers propose.

Long-term goals (outcomes), and the activities that contribute to their fulfillment (activities), are not synonymous. For example, a single grant that includes mentoring graduate students will not singularly "advance discovery and understanding while promoting teaching, training and learning" but instead the proposed activity will *contribute* to this broader goal. This seems an obvious point but it is one that is oddly missing from the BIC literature. By conflating activities, outputs, and outcomes, confusion arises about what exactly is required under BIC, for what is the PI going to be held accountable, and how it is going to be measured. In short, what exactly are researchers proposing to *do* to fulfill BIC? What specific activities are being proposed to address the larger outcomes laid out by NSF? Figure 1 outlines the relationship between outputs and outcomes under program logic modeling.

Figure 1. BIC program logic model 1



This thesis focuses on the first column of Figure 1, addressing the types of activities proposed by PIs to fulfill BIC. In short, NSF broader impacts criteria are outcomes. They are the big picture, long-term goals that NSF hopes to achieve as an aggregate of all its funded grant projects. What the PIs propose are activities that will contribute to these outcomes. Ultimately, this reorientation shifts the discussion away from 'outcome accountability' towards 'activity creation' and in doing this will provide an alternative way of understanding and assessing BIC. Further evidence of the utility of program logic modeling is that NSF's current guidance literature employs program logic model language when asking grant writers for further specifics: “what they want to do, why they want to do it, how they plan to do it, how they will know if they succeed, and what benefits could accrue if the project is successful” (NSF, 2013, chapter II.C.2.d.i).

2.5 Research Objectives

A single grantee can not be held responsible for societal goals. Instead, they can be held accountable for the results from their activity which *contributes* to the societal goal. The distinction might be minor to some, but it has large implications for those who must conceptualize and write broader impact proposals to receive funding. Therefore, it is pertinent to research BIC from the sum of its parts, its parts being activities. This thesis works to alleviate some of the confusion surrounding addressing BIC outcomes. Drawing from full proposals, this study details the types and frequencies of activities proposed by investigators to address BIC outcomes. By highlighting BIAs, this exploratory study fills a gap in the current literature, which has conceptualized all of BIC by their outcomes. Next, program logic modeling serves as a way to better BIAs in relation to BIC outcomes. This thesis then explores various dimensions of dissemination-related BIAs and compares them to the PUS and PEST models of science communication in an effort to shed light on the current strengths and opportunities for science outreach and communication. Thus, the following broad research questions drive this exploratory study:

RQ1. What are the types, range, and frequency of activities proposed by PIs to fulfill BIC?

RQ2. What are the continuities and divergences between the proposed BIAs and NSF’s five BIC outcome categories?

RQ3. What are the proposed audience types, sizes, and distance from academia for dissemination-related activities?

RQ4. How do the dissemination-related activities for the public relate to the PUS and PEST science communication models?

CHAPTER 3

METHODS

3.1 Data Set

The data set comprised 87 proposals from Iowa State University. Iowa State University is a large, land-grant Midwestern university with a strong research pedigree. The school is a member of the Association of American Universities, a 61-member organization comprised of the leading public and private research institutions in Canada and the United States. Strengthening the Professoriate at Iowa State University (SP@ISU), an NSF-funded initiative that aims to connect scientists and resources in a campus setting to better address BIC, collected the data set. In August 2012, SP@ISU sent e-mails to 429 Iowa State University faculty members who were either PI or Co-PI on an NSF proposal from 2009 to 2012, 183 of which were eventually funded. The call for proposals was open approximately two months (8/14/2012 – 10/8/2012). Seventy-six respondents submitted proposals electronically, a 5.43% response rate. Because some respondents included multiple proposals, a total of 105 were collected. Accounting for duplicates and those with no stated broader impacts, 87 proposals were coded in this study. This data set included both funded and unfunded proposals. These two categories were not separated because this thesis is focused on how PIs think about BIC, so what matters is not whether they were ultimately funded, but how PIs were proposing to address BIC outcomes.

3.2 Methodological Design

Previous BIC studies have used existing BIC outcome categories to analyze their data. Since the purpose of this study is to shift the level of focus from these long-term BIC outcome categories to the activities researchers are proposing to meet these categories, this thesis employs grounded theory as a qualitative method to identify categories that emerge from the data. In this exploratory study, qualitative methods are the most appropriate way to fully capture the greatest depth and variance of content. The emergent activity clusters will then be assessed both as part of the program logic model in relation to BIC outcomes and compared to the science communication models to better understand exactly how PIs are choosing to address BIC.

This study represents a qualitative analysis of textual data based on the guiding framework of program logic modeling and the techniques of grounded theory. While program logic model provides a general framework and some sensitizing concepts, grounded theory describes the method for inductive analysis. Thus this study is situated between inductive and deductive analysis. Grounded theory allows for salient themes to emerge from the data through a process of coding techniques including open, axial, and selective coding (Glasser & Strauss, 1967; Corbin & Strauss, 2008). Open coding is the process of breaking data down into manageable pieces and allowing concepts to emerge. First, any activity explicitly mentioned in the Broader Impacts section of the full proposal was extracted. For the purposes of this study, a broader impact activity is defined as a structured, pre-planned action that shares, teaches, promotes, communicates or otherwise engages an audience in science. Any mentions of the audience type, the resources used, and other pertinent themes were noted throughout. Then, axial coding (relating concepts to each other to form subcategories) and selective coding (grouping subcategories together to form categories and relating categories to each other) was employed to sort the extracted activities. This process required sorting activities into like categories and frequently returning to the literature for guidance and refinement.

Because grounded theory emphasizes exploration over testing, coding here is not meant to test strengths between relationships. Instead, the technique allows for ease of sorting and reporting data as well elucidating salient dimensions from the research as opposed to imposing pre-determined categories.

This thesis subscribed to validity measures consistent with grounded theory technique, including a high level of methodology and coding transparency, diligence to a lengthy iterative process of working closely with the data and the existing literature to seek alternate explanations for data trends, and working with the model in progress to embrace data that does not immediately conform (Corbin & Strauss, 2008; Steinke, 2004).

CHAPTER 4

RESULTS

Research Question 1 focused on the frequency, types, and ranges of activities proposed by PIs to fulfill the BIC. Across 87 proposals, a total of 458 activities were extracted and coded, an average of 5.3 activities per proposal. This is consistent with previous findings that proposals were more likely to include several broader impacts activities, even though it is not required to include more than one (Watts, George, & Levey, 2013). Consistent with grounded theory methodology, all clusters were derived from the scientists' categorization of their own activities. Five main activity clusters emerged from the coding process: Disseminating, Teaching, Training, Facilitating, and Researching as seen in Table 1. While this section synthesizes the major findings, the summarized data is available in the Appendix.

Table 1. BIA Clusters

	Number of activities		**Proposals with at least one activity**	
Disseminating	167	36%	70	80%
Teaching	96	21%	64	74%
Training	94	21%	76	89%
Facilitating	51	11%	40	46%
Researching	50	11%	47	54%
Total	458		87	

BIA Cluster 1: Disseminating

There were 167 proposed BIAs included in the disseminating cluster. Disseminating is the spreading of scientific information and results to a wide audience through a variety of media, formats, and channels. Although the highest number of activities was in this cluster, the majority of the activities were geared mainly towards the research community. Attending professional conferences, publishing in scientific journals, or making data available to peers accounted for 96 (21%) of the proposed dissemination activities. Of the remaining 71 activities (16%), 36 were related to disseminating information using the internet, whether by uploading information to existing websites (14), creating videos (8), a new website (4), podcasts (2), or an app (1). Other activities included disseminating findings through a more traditional media route such as news service or press releases (10), participating in public dialogues and meetings (6), or creating museum displays (3). Only a third of the total disseminating activities require the presence of the PI (presentations, dialogues) while the rest are based on disseminating materials.

BIA Cluster 2: Teaching

There were 96 proposed BIAs in the teaching cluster, the second highest volume of mentioned activities. This cluster relates to imparting knowledge in a traditional classroom setting from teacher to student through improved teaching methods and enhanced classroom materials. Activities centered on creating and enhancing classroom materials and reaching college-age students. The majority focused on integrating their research findings into current classes (58) through modules (11), educational activities (9), and homework problems (7). Curriculum integration vastly outnumbered proposals to create new academic courses and programs (12). Conducting instructional workshops (15) was also included in the teaching cluster. While the main mentioned audience for teaching activities was college-age students (44), other audiences included K-12 students (26), and K-12 teachers (8).

BIA Cluster 3: Training

The training cluster consisted of 94 BIAs. Training is providing instruction in research techniques and procedures through active participation in the laboratory or primary research space. Trainees participate in the research process and produce research products. PIs "support the training and education of graduate and undergraduate students," usually by hiring students to work directly on the project or as graduate teaching assistants. In some cases, undergraduate students are mentored by graduate students, giving the former experience and the latter mentoring experience. By far, the majority of training activities (77) were geared towards college-age students including undergraduate, graduate, and doctoral students.

External resources and partners were most frequently mentioned in this cluster. The two most salient categories of partners were those that focused on underrepresented groups and academic achievement groups. The bulk of activities comprised training activities that mentioned including members from underrepresented groups. The top-mentioned organization from which to recruit was the Program for Women in Science and Engineering (PWSE) (18), an organization started on campus in the 1980s to bolster the participation of women in the STEM fields. Other organizations from which to recruit those from underrepresented groups include the Alliance for Graduate Education and the Professoriate (AGEP) (11), and the George Washington Carver Summer Research Internship Program (5). Academic achievement organizations which frequently served as a recruiting resource include the freshmen honors program (4) and the ISU Honors program (4).

Two NSF funded programs also provided support for training activities. The Research

Experience for Undergraduates (REU) was mentioned by 20 proposals and provides indirect funds to undergraduate students to support research. The Research Experiences for Teachers (RET) was the main program through which K-12 teachers would be recruited for research experiences. Of the 15 proposals that mentioned providing research experience to K-12 teachers, 11 used the RET program. Funding supplements are available through NSF for both programs.

BIA Cluster 4: Facilitating

There were 51 BIAs included in the facilitating cluster. Facilitating includes creating collaborations, fostering partnerships, and designing programs to strengthen relationships pertinent to science. In this cluster PIs serve as organizers, planners, and program creators. The majority of these BIAs were collaborations (36), mainly creating collaborations with industry (7), other universities (7), and community groups (5) as well as fostering interactions among faculty and students (6). In 7 BIAs, PIs served as creators of internship or exchange programs. There were 6 program recruitment activities, which focused on recruiting students from underrepresented groups to join the major.

BIA Cluster 5: Researching

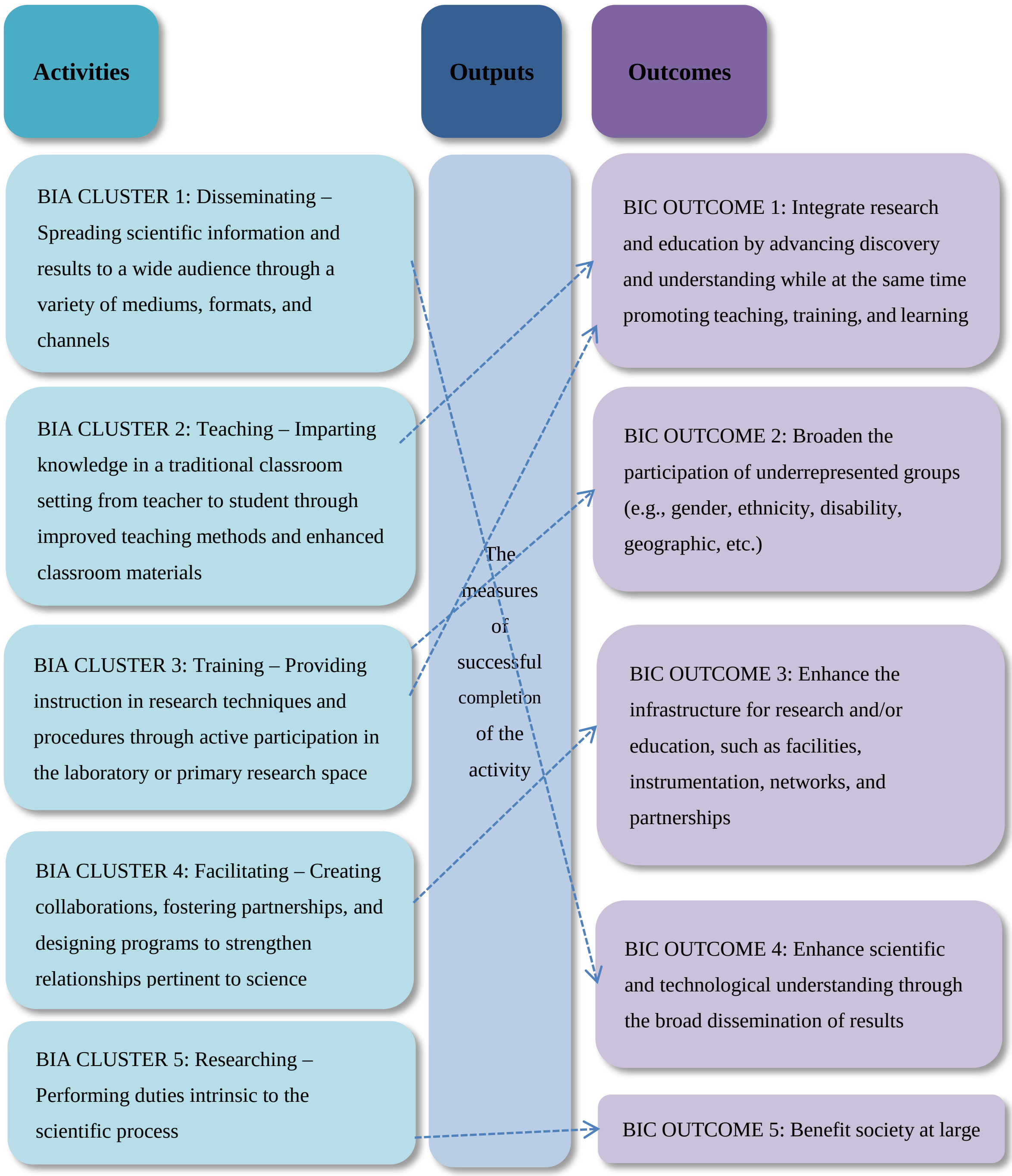
The researching cluster included 50 proposed BIAs. Research is performing duties intrinsic to the scientific process. These activities are any part of the research process or derived product that is argued to have a broader impact. Products of research include new tools and methods (9), technologies (4), and models (3), totaling 21 activities. This category contains claims that research itself would benefit various industries, such as agriculture, health, and aerospace. While the knowledge gained and products created were frequently said to be beneficial to society (27), the immediate audience for the information was research peers (11) and industry (10).

By far, the majority of broader impact activities revolve around duties intrinsic to a university faculty member. Teaching courses, enhancing curriculum, presenting at conferences and publishing in peer-reviewed journals, and researching and training the in the lab are all part of a profile of a university researcher. Moreover, two main types of audiences were mentioned – students and research peers/faculty. Whether in the classroom or being trained in the lab, college-age students constitute the main audience. To a lesser degree K-12 students were engaged through instructional workshops and outreach models. Research peers and faculty were reached mainly through conferences, journal publications, and through collaborations. In all, the majority of broader impacts activities engage those in the academic sphere. This is well within the bounds of the NSF's BIC. Roberts (2009) included five dimensions of broader impacts outcomes under "criteria for science" – infrastructure for science, broadening participation, training and education, academic collaboration, K-12 outreach and three dimensions under "criteria for society" – potential societal benefits, outreach/broad dissemination, and partnerships with potential users of research results (p. 206).

Therefore, in response to RQ1, there were five main BIA clusters with a total of 458 proposed activities. The cluster with the most activities was Disseminating, followed by Teaching and Training, and lastly the Facilitating and Researching clusters.

Research Question 2 asked about the relationship between BIA clusters found in this study and the five outcome categories of BIC. To recap, BIC asks researchers to address how their work will integrate: research and education while promoting teaching training and learning, broaden the participation of underrepresented groups, enhance infrastructure for research, enhance dissemination, and benefit society. Figure 2 charts out the details of the BIC outcomes and the BIA clusters.

Figure 2. BIC Program Logic Model 2



BIA Cluster 1 (Disseminating) most directly relates to BIC Outcome 4. PIs often propose that whatever dissemination activity they choose will enhance scientific and technological understanding. BIA Cluster 2 (Teaching) corresponds to BIC Outcome 1, where PIs propose education activities to advance discovery and understanding. BIA Cluster 3 (Training) also most often is couched in the language of BIC Outcome 1. It is also in this cluster that BIC Outcome 2 is most frequently addressed. Here PIs recruit through other organizations on campus that focus on serving underrepresented groups (mainly women and minorities) to bring trainees directly into the laboratory or primary research space. BIA Cluster 4 (Facilitating) corresponds to BIC Outcome 3. PIs explain their collaboration, partnership, and program proposals in terms of enhancing infrastructure. Lastly, BIA Cluster 5 (Researching) is used most often to address BIC Outcome 5. PIs propose that their research will have a long-term lasting impact on society at large. Therefore, in response to RQ2, the BIA clusters that emerged align very closely with the broader BIC outcomes outlined by the NSF.

Research Question 3 addressed the proposed distance from academia, audience types and sizes of dissemination-related activities. Of the 167 dissemination-related activities, 96 were geared solely towards peers and the larger research community. These activities were presenting at academic conferences and meetings (44), publishing in scientific journals (42), and making data available for use by others (10).

There were 71 dissemination activities directed towards non-scientific audiences. The main audience explicitly mentioned still remained within an academic audience. Instructors, K-12 teachers, and K-12 students, and other related audiences were referred to a total of 22 times. These activities include uploading information to educational websites (6) and development of informational materials such as brochures (3). Next, the public or citizens were mentioned 15 times as the proposed audience. The most frequent number of mentions of reaching the public was related to disseminating information through university press releases and working with the university media relations department (6), followed by stakeholder meetings and public dialogues (3). The government, government entities, or policy makers/writers were mentioned as the proposed audience 9 times. The activities with the most explicit mentions of government audiences were creating talking points and briefs (3) and disseminating through the university media channels (3). Industry or industry personnel, mentioned as the proposed audience 5 times, were mainly reached through stakeholder meetings and public dialogues (3). There were also activities directed at a certain audience, but the audience was not explicitly mentioned. For example, 3 of the proposed activities were disseminating information as part of science fairs, festivals, and competitions. These activities typically are intended for K-12 and public audiences, but were not explicitly mentioned in the proposal.

The size of the audience is dependent on the type of activity proposed. Internet dissemination activities accounted for 36 of the 71 activities. While the information is hypothetically the easiest way to reach to reach a vast number of people, making information available on the internet does not guarantee reaching a wide audience. People tend to visit the same small number of websites, regardless of the hypothetically limitless possibilities. Moreover, even if placed on a high-traffic website, the public might not even read the entire article (Manjoo, 2013). Disseminating information through the university media relations channels (10) could have a better track record of reaching the public, but again, this depends on the outlets engaged by the department. Other types of activities would include a much smaller public audience (public dialogues, for example) but this type of activity could assure reaching the public (they actually arrive as participants) as opposed to uploading information to the internet and hoping the public finds it. Therefore, in response to RQ3, the main proposed audience type for dissemination related activities was an academic audience, particularly the research peers and therefore very close to academia. The size of the audience varied depending on the proposed activity.

Research Question 4 pertained to the alignment of activities proposed for the public with the PUS and PEST models of science communication. To summarize the above discussion, the PUS and PEST models address the relationship between science engagement and the public. The PUS model is characterized by a view of a knowledge-poor, passive public and information can be supplied by the science community to fill the deficit. This model sees the relationship between science and the public as a one-way, top-down way of communication. Therefore, activities that do not have an active dialogue or input function illustrate this model. The PEST model, on the other hand, focuses on engagement and negotiation. Here the relationship between science and the public can be characterized by a two-way, inclusive style of communication where information is negotiated between the two parties. Activities that emphasize dialogue and participation by groups outside of science fall under the PEST model.

There were 71 dissemination activities directed towards non-scientific audiences and their alignment with these models of science communication are shown in table 2. The top 3 activities here were uploading information to existing websites (14), disseminating through the university's media relations (10) and creating videos (8). All these are activities that have an indirect connection to the public. Scientists are not directly engaging the public nor is there a component for dialogue in these activities.

Table 2. Dissemination related activities divided by PUS and PEST science communication models

PUS Model activities	**PEST Model activities**
Upload to website (14)	Stakeholder meetings, public dialogues (6)
Disseminate through university press channels (10)	
Create videos (8)	
Create a website (4)	**PUS + PEST Model activities**
Publish a book (3)	Museum displays (3)
Create "talking points" summaries, briefings (3)	Disseminate as part of science fairs, festivals, and competitions (2)
Presentations (2)	Increase web presence (2)
Publish in newsletters (2)	Develop an App (1)
Webinars and podcasts (2)	Disseminate through social networking (1)
Host a web portal (1)	
Create web-based materials (1)	
Development of informational material such as flyers, brochures, and posters (1)	
Sell teaching products (1)	
Meet requirements for Composites Merit Badge (1)	

As they are described in the proposals, the only activity that fits squarely with the PEST model are stakeholder meetings and public dialogues. In these activities, PIs describe working with various groups (including policy makers, journalists, and community groups) to reach a consensus about pressing issues.

Museum displays (3); dissemination as science fairs, festivals, and competitions (2); increasing web presence (2); developing an app (1); and disseminating through social networking (1) are all categorized here as having the greatest potential to contain elements from both the PUS and PEST models. For example, three grants proposed working with museums to create displays. Traditionally museums have been sites of PUS-style activities, where static exhibits rely scientific fact (Tressel, 1980). In recent times, museum displays are prompting their audiences to actively engage with, question, and provide opinions about the presented information (Roth & Lee, 2003). Therefore, depending on the way the exhibit is constructed it could include elements of both models of science communication. While a higher level of interactivity would not mean it is entirely within the PEST model, it does acknowledge the audience as an active entity that can share in the knowledge process. In the end, being able to say these activities contain elements of both PUS and PEST is contingent upon how they are implemented by the PIs and none the proposals offer this level of detail. However, the nature of the activity does offer the opportunity to include elements from both.

Therefore, in response to RQ4, even with the inclusion of the mixed activities mentioned above, PUS model activities by far dominate the type of proposed dissemination-related activities.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

By moving away from BIC outcomes, this exploratory study examined BIA in NSF grants to assess the types of activities proposed by PIs, the similarities and differences between proposed BIAs and NSF's five outcome categories, the various audience types present in dissemination-related activities, and how dissemination-related activities for the public relates to the PUS and PEST models of science communication. All of this leads to a better grasp of how PIs think about broader impacts and their role in them.

PIs propose activities most closely aligned with academia. This can be seen in the overwhelming preference to propose training and teaching activities intrinsic to higher education. Teaching courses, enhancing curriculum, presenting at conferences and publishing in peer-reviewed journals, and researching and training students in the lab or dominant research space are all part of a profile of a university researcher. Considering PIs are proposing activities that are already part of their job, it begs the question how much effort really is being put into broader impacts. This preference towards traditional teaching and training moreover translates into emphasizing one-way communication consistent with PUS in public outreach activities.

Overall, only 71 of the 458 BIAs directed towards a broader audience. When PIs did choose to interact with the public, PIs proposed more types and numbers of PUS-style outreach activities than PEST-style activities. Considering the new broader impacts guidelines are further emphasizing public outreach (NSF, 2013), this study indicates that PIs will likely rely on the less effective PUS style of communication when trying to address these new outcomes. This reinforces previous BIC studies, finding that PIs are hesitant to step outside of their comfort zones and propose activities that have broad, public outreach (Roberts, 2009; Nadkarni & Stasch, 2012; Davies, 2008; Alpert, 2009).

To address program logic modeling, the development of this emergent framework shifts PIs' focus from long-term outcomes to the more manageable BIAs. It appears that because of the way PIs structure their BIC sections, they typically pull out the BIC outcome and match one activity to its fulfillment. Because of this, the BIA clusters mostly aligned with certain BIC outcomes. This one-to-one matching suggests that PIs tend to think about broader impacts from the top-down instead of bottom-up. They are working from the outcomes to propose activities. Activity-forward thinking could actually lead to more comprehensive activities that fulfill a number of BIC outcomes. However, from a program logic modeling perspective, this is backwards. For instance, under BIA Cluster 4 (Facilitating) PIs typically stop at mentioning working with a community organization, thus addressing BIC outcome 3. Under this new framework, one well thought out activity could encompass a number of outcomes. Here agronomists could work with an organization (BIC Outcome 3) in a low-income area (BIC Outcome 2) to help set up gardens (BIC Outcome 5) and teach about soil science and plant genetics (BIC Outcome 1). Moreover, BIA clusters are malleable. They are not meant as a rubric but instead here reflect the current activities described. Recognizing BIC as the long-term outcomes they are instead gives PIs the opportunity to be more creative in their activity proposals.

However, it is important to address the output category in the program logic model. To best link activities and outcomes in the future, PIs will need to address how they will measure the successful outcome of their activity. A measureable output can include number of participants at an event, number of website views, knowledge gained (through administering a survey), or other completion measures. None of the 87 proposals in this study's data set described in any detail a measurable output indicator for any proposed activity. Working towards identifying indicators is one of the most challenging aspects of program logic modeling (McLaughlin & Jordan, 1999) but nevertheless, if in the future BIAs are going to have an impact on fulfilling BIC outcomes then output indicators will need to be comprehensively addressed going forward.

This data supports ongoing discussions regarding the responsibilities of scientists to engage in outreach. Knowing how researchers propose BIAs can guide the discussion as to how scientific outreach can be improved. If researchers are interested in continuing to focus on science education as a broader impact activity, then there needs to be some level of accountability and opportunity for engagement with science education specialists. Accountability can take place at either at some higher university level or through a more stringent NSF broader impact reporting process. Further, guides can be created for preferred activities that provide information about research-informed best practices.

If researchers are expected to engage a broader audience then they need to be provided with tools, opportunities, and incentives. First of all, researchers need to be provided with the tools to engage a broader audience. It is important to strive not only to provide researchers with outreach tools and opportunities, but also to provide insight into the needs and desires of the public. Outreach not only should focus on communicating to the public, but also communicating findings back to the scientific community. This study has shown that the research community continues to favor PUS-style activities when communicating to the public. Science communication researchers need to work closer with the research community to expose them to the assumptions that underlay science communication and how those findings can be proactively incorporated into activity design. The overwhelming preference towards PUS-style outreach shows that engaging scientists' understandings of the public(s) still has room for improvement.

Secondly, researchers need to be provided with opportunities for outreach. Here a centralized university organization could serve as a hub to create sustainable partnerships, such as a sustained partnership with a local museum where each year a new researcher works with the museum to create new content. A central university organization could also organize casual events that engage the public such as Sci-Fact showings (an old science-fiction movie is shown with a discussion by a scientist held afterwards) and Science Cafés. Organizing these events would take that responsibility away from researchers, ensure continuity in outreach initiatives, and provide opportunities for sustained community engagement, dialogue, and feedback. Another event that could be organized at the university-level to provide opportunities to researchers and others alike is a community networking fair. A community networking fair is a way to bring together all those interested in science, where researchers are not presenting per say, but are one of many kinds of participants. Here grant writers can meet and network with scholars in other fields (social sciences, humanities, arts) as well as public entities (local schools, museums, libraries, local businesses, farms). This type of event could create new, interesting partnerships between different sectors. PIs might find new ways that their research is applicable, or identify new innovative ways to fill a need through talking with those outside their field.

For those who do not feel they are comfortable with direct engagement with the public nor feel it is within their duties (Lok, 2010), providing opportunities to network with science communication and outreach specialists would also be helpful. Here researchers can include a specialist on their grant who would then coordinate the broader impacts activities. The partnership could address the lack of efficient use of science and public outreach experts (Alperts, 2009; Burggren, 2009) and could be beneficial for both scholars.

Lastly, to echo calls from other scholars (Johnson, Ecklund, & Lincoln, 2013; Nagy 2013), the university culture would need to be addressed. It is pertinent to be aware of attitudes about outreach at both the university and scientific discipline levels which can serve as both enabler and barrier to engagement (Jacobson, Butterill, & Goering, 2004; Kyvik, 2005). Secondly, science outreach currently does not count towards tenure. The pressure to publish in order to fill the tenure requirements means that researchers have little incentive to focus their time elsewhere. Research suggests that making broader impacts and science outreach activities count towards tenure could incentivize researchers (Ecklund, James, & Lincoln, 2012). In the short-term, systematically surveying university faculty to see what would drive them to perform more outreach (money, resources, recognition, professional advancement) could provide more avenues to foster incentives. In short, if we want researchers to engage a broader audience, it has to be worth their time.

Regarding the science communication models visited in this study, PUS vs. PEST might be a convenient academic bifurcation but pragmatically there are elements from both that can be incorporated into public outreach. As shown above, museum displays and dissemination as science fairs, festivals, and competitions, to name a few, have the potential to incorporate elements from both. This speaks to the importance of deriving the model from the current public outreach activities. Perhaps placing PUS/PEST on a spectrum would allow for the definition of multiple sciences, publics, and contexts to become salient. While Brossard and Lewenstein (2010) offer a rudimentary model, further studies could build off their efforts to create a model for science communication in outreach settings. Additionally, the new BIC Outcomes include improved national security, increased economic competitiveness on a national level, and "increased public scientific literacy and public engagement with science and technology" (NSF, 2013). This increased emphasis on engaging with the public adds all the more weight both to the need to further explore PUS/PEST in the context of practiced outreach and the importance of understanding exactly what types of BIAs PIs are proposing.

There are limitations to this study. One revolves around the data set. First of all, the sample is not generalizable to the entire researcher population of the university because of the selection bias. Instead, it offers insight into how PIs generally think about and choose to engage with broader impacts. The emergent categories and clusters also can serve as the basis further quantitative-based coding research. Secondly, because the grants only cover a three-year window, this offers little more than a snapshot. NSF's continual updating of its guide mean that certain outcomes are added and later dropped, thereby affecting the BIAs PIs propose. Further research based on longitudinal design could trace the change or continuity over time in what activities are proposed.

Finally, the data could be skewed in three ways. First, there were multiple grants submitted by one PI so therefore some activities could be over-represented. Secondly, since this thesis took a census-style approach and extracted all activities regardless of their frequency, there are surely activities that have been proposed and not submitted. Lastly, the respondents themselves could skew the data. Since the solicitation e-mail was sent through the university's own outreach organization, those grant writers already interested in broader impacts might be more likely to respond.

Further research could sort the data set by whether the grant was funded to see if there are similarities and differences in broader impacts. However, since this thesis was interested in how PIs thought about broader impacts, the funding outcome was not pertinent.

As Bauer, Allum, and Miller (2007) have pointed out, "as long as science and society are not identical spheres, the issues of the public's understanding of science, and of scientists' understanding of the public, are here to stay" (p. 90). By shifting the focus from unattainable BICs to pragmatic BIAs and engaging with some of the societal discussions about what is expected from research scientists, we can hopefully better align the NSF's goals with improved science outreach.

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APPENDIX

Research clusters & subcategories

	# of activities	Audience	Notes
Disseminating 167			
Peer-relevant activities (96)			
Present at conferences/meetings	44	Research community	
Publish in scientific journals	42	Research community	
Making data available	10	Research community	
Internet activities (36)			
Upload to website	14	Public (2), students, K-12 teachers (4), faculty (2)	online repositories --placed on educational website
Create videos	08	K-12 (2), non-scientific audience (2)	Movies showing duties of scientists – day in the life – principles of field – findings shown through digital illustration-- -part of a museum exhibit and also posted to websites -integrate with IPod for classroom download -broadcast on YouTube
Create a website	04		
Webinars and podcasts	02	Policy writers (2), leaders	
Increase web presence	02		
Host a web portal	02		
Create web-based materials	02	Public	
Develop an App	01	K-12 students	
Disseminate through social networking	01	Public	Facebook, Twitter, LinkedIn, Wikipedia entries
Other materials (35)			

Disseminate through university press releases, (university press channels)	10	Government (3), general public (6), stakeholders	Media outlets, ISU media relations, ISU press service, ISU news services (3)
Stakeholder meetings, public dialogues	06	Public (3), government agencies, journalists (2), policy makers (2), economists, agronomists, extension agents, K-12 community, joint advisory committee	
Museum displays	03		Science museum – children's science museum
Publish a book	03		make electronically available (2)
Create "talking points" summaries, briefings	03	Government (3), policy makers (3), University personnel (2)	
Disseminate as part of science fairs, festivals, and competitions	03	K-12 Students	Virtual Reality Educational Pathfinders (VREP), City of Ames Community School District, Iowa Children's Water Festival, Iowa Science Olympiad, ISU IT-Olympics, Cyber Defense competitions, Regional science bowl
Presentations	02	Policy makers, citizens, *historically Black university*, stakeholders	
Publish in newsletters	02	Local industry (2), K-12 teachers (2)	
"Development of informational material such as flyers, brochures,	01	Students, counselors, community	

and posters"		colleges	
Sell teaching products	01	Students, instructors	
Meet requirements for Composites Merit Badge	01		Boy Scouts
Teaching 96			
Classroom Materials (58)			
Incorporate findings into classroom	18	College students (16)	CELT
Create class module	11	K-12 Students (8), College students (2)	*Science Bound*, CELT, *ATEEC*, Iowa-Cedar River Basin (ICRB)
Develop educational activities	09	K-12 students (4), teachers, faculty, students	Iowa Learning Farms (ILF), Virtual Reality Educational Pathfinders (VREP), Summer Institute on Earth-Surface Dynamics, Aquatic insect education program, *PWSE*
Create homework problem	07	College students (7)	
Create case study	05	College students (5)	
Create curriculum	04	K-12 teachers (3), UGs	
Create demonstration	02	K-12 students, College students	*PWSE*
Create exercise	02	College students (2)	
Workshops (15)			
Conduct instructional workshops	15	K-12 students (5), K-12 teachers (3), Faculty (2), college students (2), neighborhood associations, K-12 parents, Policy writers, industry leaders, NSF-funded trainees,	ATEEC – Iowa K-12 program in the NSF-ERC on Biorenewable Chemicals at ISU, Science Bound, PWSE, Plant Genome Outreach Program, ISU Extension

		Postdocs	
New Academic Programs (12)			
Create new course	09	College students (6), non-traditional students	
Create training program	02	Postdocs, College students	
Develop a minor	01	Non-engineering students	
Establish a new PhD program	01		
Other Teaching efforts (11)			
Visit classrooms as guest lecturer	08	K-12 students (6), High school teachers,	ISU's summer programs including RETs and REUs, *PWSE*
Host field trips to facility	03	K-12 students (2)	
Facilitating 51			
Collaborations (36)			
Create collaborations	27	Other universities (7), Industry (7), Community groups (5), international faculty (5), Government (3), K-12 teachers,	*Minority-serving institutions*(4), CB[1022], ISU I/UCRC Center, *ethnic neighborhoods and underrepresented communities*, NEES[1097], IOWATER Volunteer Water Quality Monitoring Network, NSA-designated Information Assurance Center
Create consortium, working group	02	Faculty	
Foster interactions	06	Faculty (3), College students (3)	
Coordinate technology transfer	01		
Program Recruitment (6)			
Recruit students to program	06	College students (2), High school students (2)	*Science Bound*, *Minority and underrep students from historically Black universities*

			- All mention underrepresented groups, minorities, women, those with disabilities
Exchange/Internship Programs (7)			
Develop internship program	04	Master's teachers, college students (2), fellows	Iowa Integrated Innovation and Commercialization Network, John Deere, Institute for Combinational Discovery
Develop international exchange program	02	College students (2), early career scientists	
Develop national exchange program	01	Curators, College students	
Other (2)			
Support student outreach efforts	01		ISU Water Environment Federation student chapter
Organize math night	01	K-12 students	
Mentoring 94			
Support training	26	Postdoc (10), High school teachers (1) High school students (5) Undergraduate students (18), Graduate students (15), PhD (8) College Students [26]	Minority affairs, Program for Women in Science and Engineering PWSE (5), Preparing Future Faculty (PFF), Ames Community School engineering internship program, Freshman Honors Program, Miniority serving uni, SPEED (2), Ames High School partnership, Council for Opportunities in Education, Alliance, Plant Genome Outreach Program (3), REU (2)
Integrate into research/lab	23	Undergraduate students (12), Graduate students (6), Postdocs (5),	PolarTREC (2), RET (5), Alliance for Graduate Education and the Professoriate (AGEP) (5), Alliance for Minority

		K-12 teachers (7) College students [16]	Participation (AMP), REU (12), CELT'S Preparing Future Faculty (PFF) (2), George Washington Carver internship program (2) PWSE (6), Research for Credit Program, SP@ISU, NSF ADVANCE, HCI Program, Summer Program for Enhancing Engineering Development (SPEED) (2), Dept of Energy Science UG Lab internships (SULI), Minority affairs
Provide research experiences	20	K-12 teachers (4), High school students (2) Undergraduate (14), Graduate (10) PhD (5), Postdocs (1) College students [15]	ADVANCE, Alliance, Minorities in Ag, Freshmen Mentor Program REU (2), AGEP , Graduate Assistant in Areas of National Need (GAANN), George Washington Carver (2), Honors Program (2), PWSE
Mentor	09	K-12 students (2), Faculty (1), Undergraduate students (6), Graduate students (6), Postdoc (3) College students [7]	PWSE (4), McNair, Freshmen Honors, REU (2)
Hire/employ	16	K-12 teachers (3), high school students (2), Undergraduate	RET (2), George Washington Carver internship program (2) Alliance

		students (9), Graduate students (8), PhD (6), Postdoc (3) College students [13]	PWSE (2) McNair Scholars Pipelines program REU AGEP
	94	College Students [77]	*Program for Women in Science and Engineering- PWSE* (18) Research Experience for Undergraduate- REU (20) Research Experience for Teachers- RET (11) Alliance for Graduate Education and the Professoriate -AGEP (7) George Washington Carver internship program (5) Freshmen Honors (4) Alliance (4) CELT'S Preparing Future Faculty-PFF (3) Plant Genome Outreach Program (3) PolarTREC (2) Summer Program Enhancing Engineering Development SPEED (2) McNair Scholars (2) Minority Affairs (2) ADVANCE (2) SPEED (2) Dept of Energy Science UG Lab internships (SULI) SP@ISU Pipelines program Graduate Assistant in Areas of National Need-GAANN HCI Program Minorities in Ag Research for Credit Program Freshmen Mentor Program

			Ames Community School engineering internship program Ames High School partnership Council for Opportunities in Education
Researching 50			
Provide for new products = technologies (4), equipment (5), methods (4), tools (5), models (3)	21	Lab participants(2) Aerospace industry Oil industry Industry partners Government agencies (2) Policy makers Small business owners Community leaders	
Knowledge gained	29	Research peers (11) Higher Education (2) Electrical engineering Meteorology Multiple access communications research Industry Chemicals research community Drug developers (2) Agriculture (3) Government NGOs Policy makers Public	

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