FRAMING IN SCIENCE COMMUNICATION: INFLUENCING THE PUBLICS' BEHAVIOR TOWARDS THE ENVIRONMENT

by

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ABSTRACT OF THE DISSERTATION

Framing in Science Communication: Influencing the publics' behavior towards the environment

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Our current geological period, known as the Anthropocene (from the industrial revolution to present), is characterized by scholars as the time in which humans have had a disproportionate, often negative, impact on the earth's bio-physical systems. Global climate change is arguably *the* major issue to emerge from this human impact and has been cited as a driver, or aggravator, of many ecological problems (e.g., phenology shifts and mismatches, invasive species establishment, biodiversity loss). Beyond the bio-physical threats climate change poses, addressing climate change issues through policy and individual action has been particularly problematic because it has been subject to politicization through active media campaigns to highlight uncertainties in climate science to sow doubt of climate change's existence. This rampant politicization of science, particularly climate science, makes it an especially difficult issue to address. Scholars have suggested that direct engagement with local communities and persuasive science communication as two opportunities to combat these misinformation campaigns and influence public decision-making. This area of how communication influences public

behavior and outcomes has been little explored in the ecological literature, and even less so the intentional employment of frame theory from the communication sciences.

In this dissertation, I aim to investigate how framing ecological science communication can affect the outcomes (e.g., science literacy, trust of science, behavior change, valuation of the issue, support for science), in the context of public participatory research (e.g., citizen science) and direct scientists-to-public interfacing, in the overarching context of climate change. In my first chapter, I investigate what minimum scale of re-framing climate issues showed significant response from participants. Particularly, this work seeks to answer, can we elicit positive responses towards environmental issues from identity groups who would otherwise not be supportive of climate change intervention. In my second chapter, I test how framing of scientist-driven public engagement (i.e., citizen science) impacts outcomes for participants (science literacy, trust and views of science) using the principles highlighted in chapter 1. In my third chapter, I developed a framework for employing framing in communicating ecological issues by practitioners. The results of my dissertation research can influence and improve how practitioners of science and science communication create and disseminate messages about their science to elicit particular responses and behaviors from the public.

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A PhD is a surprisingly expensive endeavor (even if your tuition is paid for), so I would like to thank all of the institutions and organizations who funded my research, conference travel, and other expenses to make a successful graduate degree possible. In particular, I would like to acknowledge the women of the Associate Alumnae of Douglass College (AADC). Douglass Residential College and then the AADC has been instrumental in supporting me not just financially, but also providing inspirational support for what it means to be a woman in science. I think it is important for all scholars to have a support network, and the AADC has been particularly important to me.

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Finally, I would like to say a tremendous thank you to my advisor, Dr. Rebecca Jordan, for everything she has done for me in this process. I could not have asked for a better advisor, mentor, and friend. There are not enough words for me to express how grateful I am for everything and all the support and guidance you have shown me throughout these past five years. You are an inspiration as a scholar, a mother, a friend, and a generally amazing human being. I hope I can be half as amazing for my future students as you have been for me.

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Tables and Figures

Introduction

The current geological period, coined as the Anthropocene (from the industrial revolution to present), is characterized by scholars as the time in which humans have had a disproportionate, often negative, impact on the earth's bio-physical systems (Crutzen and Stoermer 2000). Global climate change is arguably *the* major issue to emerge from this human impact and has been cited as a driver, or aggravator, of many ecological problems (i.e., phenology shifts and mismatches, invasive species establishment, biodiversity loss). Beyond the bio-physical threats climate change poses, addressing climate change issues through policy and individual action has been particularly problematic because it has been subject to politicization through active media campaigns to highlight uncertainties in climate science to sow doubt of climate change's existence (Zehr 2000). This rampant politicization of science (Pielke 2002), particularly climate science, makes it an especially difficult issue to address. Scholars have posited two ways that scientists and practitioners can influence decisions about climate change, one being engaging directly with local communities (Donlan et al. 2003) and the other being persuasive science communication (McNutt 2013). What has little been explored in the ecological literature is investigating the role of community engagement and persuasive communication in addressing ecological issues, and more so the intentional employment of frame theory from the communication sciences.

What is framing?

Up until the mid 1990's, framing was a term used almost exclusively when referencing media, the mass communication industry, and research. Indeed, Gamson and Modigliani (1987) coined the concept "media frame" ami a story line that gives definition and meaning to an issue. In the late 1990's Scheufele (1999) developed a process model of framing, grounding the framing research in a theoretical framework where he identified two dimensions of framing research (frame type and frame operationalization) and the subsequent four key processes for future research in framing. This foundation allowed for more rigorous investigation into framing effects and a means in which researchers in other disciplines could engage the idea of framing outside of media studies. In the more modern context, framing has been used in a number of contexts outside of the media to refer more broadly to narratives that communicate information to particular audiences and often times the importance of that information (see Nisbet 2009, for a discussion). In the scientific realm, framing has been employed by the media and researchers to promote particular scientific agendas and engender support for controversial topics. Nisbet et al. (2003) did one of the first studies investigating how media framing affects scientific agendas, looking at the stem cell controversy. These authors found that the frame employed by mass media (a moral/ethics issue) brought this research to the forefront of the political agenda, ultimately likely driving the politically imposed limitations in stem cell research. Later, Nisbet and Mooney (2007) argued that for successful science communication to the public, the communication should focus on the morality of the research, not necessarily the facts.

Why is framing important?

This push to step away from the clinical and detached mode of traditional science communication highlights the importance of two current realities in science: (1) funding for scientific research is limited by governmental imposed budgets and (2) public support for and interest in science has the capacity to dictate government interests. Additionally, many of the global environmental and ecological problems (e.g., climate change, coral die-off, species extinction) require collective and individual action to address these issues. Due to the current status of climate science communication, researchers have begun to acknowledge framing as a powerful tool and asset when addressing issues within the sciences and to the public at large (Wiederhold 2011). Because framing can promote certain interpretations and subsequent solutions by emphasizing particular facets of an issue (Entman 2004), frames can help to simplify complex scientific issues by placing greater weight on some considerations than others. Frames can also provide common reference points and meaning between experts, the media, and the public (Groffman *et al.* 2010), improving communication of complex scientific information to the public.

In all of these previously mentioned examples of framing in science communication, there is still a reliance on top-down dissemination (scientists to media to public) of framing where the media serves the traditional role as the mediator. There are few examples of scientists considering framing in the communication of scientific research. A notable exception is scientist EO Wilson (Wilson 2006), who partnered with evangelical Christian leaders to reframe environmental stewardship in terms of morality and ethics nested within a biblical context. By re-framing climate issues to be more palatable to this particular audience, Wilson has had success in engaging an audience who did not attend to climate issue because of the scientific foundation (Groffman *et al.* 2010). While there has been an increase in the democratization of science through the popularization of citizen science and public participatory research, there has been little work investigating the role of framing in this new paradigm of direct scientist to public engagement.

This dissertation research, in the context of climate change, broadly seeks to address how framing impacts the publics' views of science as a practice, support of science, willingness to address climate issues in the context of being outdoors, views of citizen science and views of stewardship. As noted previously, framing has been shown to drive opinion and behavioral change through media consumption, but the effect of employing framing in public participatory research programs has yet to be investigated. I aim to explicitly investigate how framing can affect the outcomes (e.g., science literacy, trust of science, behavior change, valuation of the issue, support for science) in public participatory research (e.g., citizen science and similar) that is focused on ecological issues in the context of climate change.

The objectives of my dissertation are the following:

1. Chapter 1 seeks to investigate what minimum scale of re-framing climate issues showed significant response from participants. Particularly, this work seeks to answer, can we elicit positive responses towards environmental issues from identity groups who would otherwise not be supportive of climate change intervention.

2. Chapter 2 seeks to test how framing of scientist-driven public engagement (i.e., citizen science and similar) impacts outcomes for participants (science literacy, trust and views of science, etc.) using the principles highlighted in chapter 1.

3. Chapter 3 developed a framework for employing framing in communicating ecological issues by practitioners. Particularly, investigating if there are parallels ecologists, or ecology communicators, can draw from the framing literature in other scientific disciplines (e.g., public health and vaccination).

Why in the context of climate issues?

Climate change has been described as one of the biggest problems of this century (Ruhl and Salzman 2010) and a "wicked problem" (Levin *et al.* 2012); involving much complexity, in which the public struggles with the science behind it. Climate change challenges peoples' understandings because 1) it is spatially and temporally vast 2) it entails varying levels of uncertainty and 3) it has been highly politicized. Additionally, while there is always variability and scientific uncertainty in data and data projections, there has been an active media campaign to highlight specifically the uncertainties in climate science and question climate change's existence and potential impacts (Boykoff and Boykoff 2007, McCright and Dunlap 2011). Because of these numerous complexities in the science, the popularity of the issue, and current polarized climate surrounding climate change, using climate change would be an excellent test if frames have a true impact.

Why in the context of citizen science?

Citizen science has been widely promoted as a tool for researchers to gather large quantities of data while benefiting the public that engages in it. Additionally, there are reported benefits of citizen science for the enterprise of science, with citizen science promoting increased support for science (Bonney *et al.* 2009). While some citizen science programs have reported increased participant knowledge (Jordan *et al.* 2011), increased civic awareness and engagement (Nerbonne and Nelson 2004), and increased participant engagement in scientific thinking (Trumbull *et al.* 2000); many citizen science programs do not have any evaluation of the participant outcomes but tout these benefits for their participants (Shirk et al 2012). The continued progression and development of citizen science as its own unique discipline will likely be contingent on development of theory driving citizen science usage. As a part of developing this theory, broad and persistent evaluation of citizen science programs, consideration and integration of theory from other disciplines (i.e., communication, media studies, psychology, sociology), and experimental studies are much needed. My own work here comes at the nexus of these areas highlighted in driving citizen science theory, particularly in consideration of developing and promoting desired participant outcomes.

Chapter 1

I sought to investigate what the minimum scale of re-framing climate issues showed significant response from participants.

Abstract: Effective communication of science to the general public is important for numerous reasons, including support for policy, funding, informed public decision-making, among others. Prior research has found that scientists participating in public policy and public communication must frame their communication efforts in order to connect with audiences. A frame is the mechanism that individuals use to understand and interpret the world around them. Framing can encourage specific interpretations and reference points for a particular issue or event; especially when meaning is negotiated between the media and public audiences. In this study, we looked at the effect of framing within an environmental conservation context. To do this we had survey respondents rank common issues, among them being environmental conservation, from most important to least important for the government to address. We framed environmental conservation

using three synonymous terms (environmental security, ecosystem services, and environmental quality) to assess whether there was an effect on rankings dependent on how we framed environmental conservation. We also investigated the effect of individuals' personality characteristics (identity frame) on those environmental conservation rankings. We found that individuals who self-identified as environmentalist were positively associated with ranking highly (most important) environmental conservation when it was framed as either environmental quality or ecosystem services, but not when it was framed as environmental security. Conversely, those individuals who did not rank themselves highly as self-identified environmentalists were positively associated with environmental conservation when it was framed as environmental security. This research suggests that framing audience specific messages can engender audience support in hot-button issues.

This chapter, and previous abstract, has been published as a scientific article in *Frontiers in Environmental Science* (see citation below).

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> 3(36). DOI:10.3389/fenvs.2015.00036.

Chapter 2

I sought to employ and investigate these simple re-framing techniques of adjusting language, visual presentation, and rhetoric in the context of a citizen science/crowdsourcing program.

Abstract: Recent literature has acknowledged the conflation of citizen science and crowdsourcing, as they share superficial similarities in their modes of participant engagement. However, these project types diverge in participant motivation, rhetoric, size, and interfacing. This disparity suggests that the framing of these projects may significantly influence participant outcomes (e.g., views and trust of science, identity, and science literacy) and engagement. To investigate the impact of framing, a web-based phenology research program was created where half the participants were engaged in a citizen science framed program and the other half in a crowdsourced framed project. Post-participation we see that there are indeed significant differences in participant outcomes between frames. This work can help guide practitioners using public participatory research in thinking about design and program evaluation as a part of their project development and stimulate further rigorous research about best practices in engaging the public in scientific research.

This chapter is formatted for *BioScience* and is submitted for review (Sorensen and Jordan, *in review*).

Chapter 3

I sought to develop a framework for employing framing in communicating ecological issues by practitioners.

Abstract: Ecological problems have recently been politicized and subject to misinformation campaigns to divide public belief and action on these issues. Given the urgent need to address this phenomenon, we suggest that desired public action can be motivated through intentional employment of framing in science communication. In this

paper, we sought to evaluate the effect of framing about ZIKV (Zika virus) communication, by explicitly connecting two ideological congruent ideas (i.e., protecting self = protect others) for individuals, and measuring the potential shifts in resident behavior towards willingness to comply with mosquito prevention action. Post framing intervention, we found a significant increase (N=26, p<0.001) in individuals willing to take preventative action against mosquitoes. By methodically investigating best-practices in communication, this study and others, can help practitioners mobilize communities to address large-scale ecological problems. Additionally, the principles outlined here, connecting ideological congruent ideas*,* may be transferrable to other communication efforts.

This chapter is formatted for *Frontiers in Ecology and the Environment* and is submitted for review (Sorensen, LaDeau, and Jordan, *in review*).

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Chapter 1: Effects of Alternative Framing on the Publics Perceived Importance of Environmental Conservation

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Abstract

Effective communication of science to the general public is important for numerous reasons, including support for policy, funding, informed public decision making, among others. Prior research has found that scientists participating in public policy and public communication must frame their communication efforts in order to connect with audiences. A frame is the mechanism that individuals use to understand and interpret the world around them. Framing can encourage specific interpretations and reference points for a particular issue or event; especially when meaning is negotiated between the media and public audiences. In this study, we looked at the effect of framing within an environmental conservation context. To do this we had survey respondents rank common issues, among them being environmental conservation, from most important to least important for the government to address. We framed environmental conservation using three synonymous terms (environmental security, ecosystem services, and environmental quality) to assess whether there was an effect on rankings dependent on how we framed environmental conservation. We also investigated the effect of individuals' personality characteristics (identity frame) on those environmental conservation rankings. We found that individuals who self-identified as environmentalist were positively associated with ranking highly (most important) environmental conservation when it was framed as either environmental quality or ecosystem services, but not when it was framed as environmental security. Conversely, those individuals who did not rank themselves highly as self-identified environmentalists were positively associated with environmental conservation when it was framed as environmental security. This research suggests that

framing audience specific messages can engender audience support in hot-button issues such as environmental conservation and climate change.

Introduction

Communicating science to the public is cited (Bauer 2008; Nisbet and Scheufele 2009; Besley and Tanner 2011) as an important, but potentially difficult, task for many scientists. Without accurate and persuasive conveyance to the public, science can often have little broader value (McNutt 2013). In important issues such as global climate change, the scientific consensus does not translate to broader public. For example, a review of thousands of refereed scientific publication reports a 97% consensus among scientists of anthropogenic-induced climate change (Cook *et al.* 2013). Yet, among the American public, only 39% identify as "concerned believers" in climate change (Gallup 2014) and just 57% of the American public believe human activities are to blame for climate change (Gallup 2014). Another example area that has recently been a highly disputed public controversy is public health and in particular, the choice to vaccinate. False information published in the late 1990's (Wakefield *et al.* 1998) concerning an autism-vaccine link has had long lasting impacts on public health communication continuing to this day (Flaherty 2011). In a recent study on vaccine safety, half of the respondents reported concern for adverse effects and 11.5% refused a recommended vaccine (Freed *et al.* 2009). These examples make it is clear the importance for the general public to receive and use the correct scientific information given the ubiquitous choices they make about scientific issues, and take subsequent action on a daily basis.

Framing can promote certain interpretations, evaluations, and solutions by emphasizing particular facets of an event or issue (Entman 2004). Frame theory, initially defined by Goffman (1974), is the mechanism in which people interpret what is going on around them. Frames also help to simplify complex issues by placing greater weight on some considerations and arguments rather than others, showing why an issue might be a problem, who or what might be responsible, and what should be done. Additionally, frames can provide common reference points and meaning between experts, the media, and the public (Groffman *et al.* 2010). A powerful example of framing was offered by scientist EO Wilson (Wilson 2006), who partnered with evangelical Christian leaders, in discussing environmental stewardship in terms of morality and ethics. In reframing, they are engaging an audience that might not attend to climate change issues because of the scientific foundation (Groffman *et al.* 2010). In the context of this paper, we define framing as certain written word constructs that may change or influence interpretation of information.

While the success of public uptake and interaction with scientific information can be based on a number of different variables such as: public trust (Haerlin & Parr 1999), personal interaction (Kempe *et al.* 2011; Silvertown *et al.* 2011), attitudes (Riddiough *et al.* 1981), and awareness (Littledyke 2008); how scientists frame science to public in their communication is equally as important. Academics and professionals have long acknowledged framing as a powerful tool and asset when addressing issues within the sciences and to the public at large (Levin *et al.* 1998; Wiederhold 2011). Research on framing effects have found that scientists participating in public policy and public communication must frame their communication efforts to connect with audiences (Nisbet Brossard and Kroepsch 2003; Nisbet and Huge 2006; Nisbet and Mooney 2009).

Considering the power and influence of frames in communication, capitalizing on framing as a common practice for science communication is relatively unseen. Indeed, Nisbet and Mooney (2009) detailed the influence and effectiveness of frames: from motivation; influencing behavior; garner support for issues; finding common ground; and defining issues.

Additionally, identity frames can impact decision-making and interpretations of information. Identity frames can classically be defined as a cognitive framework or scheme of the characteristics belonging to individuals, or categories of individuals, we identify within and from our social experiences (Abrams & Hogg 1987; Guichard 2001). For example, in a study on the effect of identity on European Union officials, researchers found that personal identity associated with home-country affiliation affected member political actions and beliefs while participating in inter-governmental policy development (Egeberg 1999). These personal identity frames can have important implications for decision making by the public on particular divisive or emotionally charged issues such as environmental protections and climate change.

In this paper we seek to address the issue of framing in science communication from an environmental context. Particularly, we focus on the effect of framing environmental conservation in terms of perceived importance by the public. We also seek to investigate the potential connection between individuals' identity frames of common conservation terms within an environmental context.

Methods

To assess the effect of framing of environmental issues on individuals' perceived importance of these issues, we generated items on various aspects of environmental issues and identity as a part of a broader survey on local greenspaces, environmental beliefs, environmental knowledge, views of the nature of science, and personality factors. These 30 survey items were vetted through focus groups for internal consistency and validity. Environmental knowledge survey items were taken from the National Environmental Education & Training Foundation/ Roper Research on Environmental Literacy in America (1999). This metric is widely known and quite robust to allow us to compare our results to other studies. Survey items for this paper were composed of five-point Likert-scale and dichotomous choice (see appendix for survey items).

To assess framing in an environmental communication context we generated a set of issue ranking items. Participants were asked to rank ten issues from 1 to 10 of importance for the American public to address or solve, where a ranking of 1 was most important and a ranking of 10 was least important. Issues could not share rankings of importance, thus individuals' had to prioritize some issues over others. Seven of the ten issues participants had to rank were: curing cancer; improving quality of US education; decreasing crime and drug use; reducing health care costs; decreasing poverty; growing the US economy; and reducing the budget deficit. Three of the issues were terms that are used synonymously in popular and refereed environmental literature: improving environmental quality; improving environmental security; and improving ecosystem services. Of these ten issues, we were interested in the potential differential ranking of environmental quality, environmental security, and environmental services. These three terms, in the context of improving or garnering support for conservation of the natural environment, have the potential to confer differing levels of importance to the public. Thus, framing, is this context, could be impacting scientific communication and public decision-making in a way we do not yet know.

Individuals living in six townships near a public university in New Jersey were mailed paper surveys with pre-stamped return envelopes. Those individuals were chosen by random sampling the online white pages listing for the six focal townships. 75 surveys were sent to each township, totaling to 450 surveys sent but given that our method relied on dated addresses, we were not surprised to find that a number of surveys were returned unopened. This meant our effort was 380 surveys making our response rate 19.5%. There were 74 completed returns fairly evenly distributed across the townships. All surveys were kept anonymous and no identifying information was asked of participants.

All statistical analyses were performed in Minitab 17 statistical software package (2010). A Principal Components Analysis (PCA) using a correlation matrix was used to inspect associations among Likert self-report being an environmentalist, having environmental knowledge and rank of terminology (i.e., environmental security, environmental, quality, and environmental protection). The purpose of our study was to look for emerging associations and not to test hypotheses. Therefore, for this research note, we chose to use PCA to inspect for preliminary associations only.

Results

Of the three terms, environmental quality was ranked the most important by participants with an average ranking of 4.730 out of a possible 10 points. Environmental security was ranked second with an average ranking of 6.290 out of a possible 10 points. Environmental services was ranked as the least important with an average ranking of 7.435 out of a possible 10 points.

We constrained our PCA to three components given that we had only five variables. These three components explained 77% of the variance in our dataset. To inspect for associations, we used loadings over ± 0.300 as a measure of weight of the construct on that component (See Table 1). For PC 1 (principal component), we found that labeling one's self as an environmentalist is positively associated with ranking highly environmental quality and ecosystem services. This was not the case, however, for environmental security. Environmental security and environmental knowledge were associated along PC 2 with the other variables not loading highly. On PC3, self-reported environmentalist and ecosystem services were associated and negatively associated with environmental security.

Discussion

It is clear from this research, the impact of how we communicate scientific concepts extends beyond what was previously thought. Indeed, individuals who self-identified as environmentalists were more likely to associate and respond strongly with words like service and quality, whereas those individuals who did not identify as environmentalists may find these words equally or less appealing than the word security. This finding can have definite impacts for scientists as they communicate issues within the public forum to various groups of people, particularly those people who are divided on their personal and political values. Schudlt *et al.* (2011) found that individuals who identified as

Republicans were significantly affected by question wording, and subsequently were less likely to endorse global warming than when it was framed as climate change, where as Democrats were equally responsive to both terms.

Successful science communication is not only critical for a supportive, literate, and engaged public, but key to success of future generations (Durant *et al.* 1989; Ziman 1991; Cajas 2001 Slovic *et al.* 2013). Communicating important scientific concepts to the public at large has proven to be a messy and complicated challenge with varying levels of success. This disconnect between scientific findings and public opinion in the context of climate change clearly demonstrates this. While science communication is a complex issue, frames play an important role. In a recent study from the United Kingdom, researchers found that shifting climate action discussions from a negative frame (possibilities of losses) to a positive frame (possibilities of losses not materializing), participants had stronger environmental behavior intentions despite high uncertainty conditions (Morton *et al.* 2011). The potential to overcome uncertainty in public discussions of climate change is undeniably important.

The implications of this research suggests that how scientists frame their communications in an environmental context to the public, and particular audiences within the public, can have the potential to influence person decision making and policy. Further, similar findings in previous work on climate change found reframing climate change as a public health issue engendered greater response from participants (Maibach *et al.* 2010). Additionally, Bain *et al.* 2012 found that framing climate change action to climate change deniers as increasing consideration for one another or improving technological/economic development, those individuals were more supportive of pro-environmental actions. This re-framing from avoidance of environmental harm to improvement of society motivated individuals traditionally left out of the climate change action conversation.

A simple difference in framing environmental protection and conservation three different ways (security, quality, and services) seemed to significantly affect the importance of addressing the issue for the participants. Additionally, identity frames seem to also play an important role in participant decision-making. Within this work we see distinct separation in the rankings of importance between those individuals who self-identify as environmentalists and those who do not. Individuals who most identify as environmentalist seem to respond more positively to environmental conservation in terms of protecting quality for its own sake. Whereas those individuals who least identified as environmentalists seem to respond more positively to protecting the environment when it was framed as a mater of national security. The impact of these identity frames in participant responses, and the associated implications on decision-making, highlights the additional complexity when developing successful communication strategies. This suggests awareness of key audience personality characteristics could help tailor messages about important scientific issues to make those audiences more receptive, as supported by various studies work (Wilson 2006; Groffman *et al.* 2010).

Further work is needed to investigate framing phenomenon in environmental communication on a broader scale. Concurrently, particular predictive linkages between personality and demographic characteristics should be investigated further. Numerous studies have highlighted the connection between personality characteristics and political leaning (e.g. Verhulst *et al.* 2012; Lewis & Bates 2011). These links between political affiliations and personal and policy decisions have been well documented, which have broad implications for issues such as climate change. A recent study on predictive characteristics of climate change deniers found that, while controlling for political leaning, race, and gender, being a conservative white male was significantly linked to indicators of climate change denial (McCright and Dunlap 2011).

Additionally, work from personality psychology shows that personality types of Ph.D climate change scientists and that of the general public in the U.S. differ greatly in core components. Using the Myers-Brigg Type Indicator personality test, Weiler *et al.* (2012) found that climate scientists were significantly more likely to prefer sensing over intuition while taking in new information around them, and judging over perceiving while dealing with their surroundings than the general public. Thus, these demographic characteristics that have the potential for predictive power in audience decision-making can greatly help scientists frame communication efforts appropriately.

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Table 1.1 Principal Components Analysis (PCA) for the first three components.

	PC1	**PC2**	**PC3**
Environmentalist	-0.508	0.197	0.527
Environmental Knowledge	-0.252	0.739	0.020
Environmental Quality	0.544	-0.118	0.239
Environmental Security	0.376	0.569	-0.480
Ecosystem Services	0.491	0.279	0.659

Chapter 2: Framing in Ecological Citizen Science and Crowdsourcing Projects: Impacts on Participant Outcomes

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Abstract

Recent literature has acknowledged the conflation of citizen science and crowdsourcing, as they share superficial similarities in their modes of participant engagement. However, these project types diverge in participant motivation, rhetoric, size, and interfacing. This disparity suggests that the framing of these projects may significantly influence participant outcomes (e.g., views and trust of science, identity, and science literacy) and engagement. To investigate the impact of framing, a web-based phenology research program was created where half the participants were engaged in a citizen science framed program and the other half in a crowdsourced framed project. Post-participation we see that there are indeed significant differences in participant outcomes between frames. This work can help guide practitioners using public participatory research in thinking about design and program evaluation as a part of their project development and stimulate further rigorous research about best practices in engaging the public in scientific research.

INTRODUCTION

Scientific literacy has been cited as an important component of a knowledgeable, supportive, informed decision-making public (Sinatra et al. 2014). Indeed, the public must make decisions about scientific issues and take actions in their personal lives based on scientific research. In order to effectively consider the science behind many issues, the public must not only be familiar with the content knowledge of the science, but also the practices of science. Many individuals learn about science in informal settings such as museums, educational centers, interpersonal relationship, and primarily, the media (Nisbet and Kotcher 2009). Recently, public engagement in real scientific research (i.e., citizen science, crowdsourcing, and other variants) has been championed widely as another pathway for developing public scientific literacy and knowledge (Bonney et al. 2009).

Public engagement in, and contribution to, science has taken many forms in its development and implementation into scientific practice. The two forms most commonly cited in the scientific literature are crowdsourcing and citizen science, which can share superficial similarities in their modes of participant engagement (i.e., online data collection or participant interface) and participant motivation. Having these projects online allows project organizers to reach a wide audience of potential participants and reduce traditional barriers to project participation such as cost, distance, and time. Studies of citizen science and crowdsourcing also share overlapping reported drivers of participant motivations. Recent research investigating motivation for participating in crowdsourcing or citizen science has found commonalities such as: project interest (Kaufmann et al. 2011, Rotman et al. 2012); enjoyment (Nov 2007, Hossain 2012); learning something new (Raddick et al. 2009, Stewart et al. 2009); community and identity (Wasko and Faraj 2000).

Citizen Science

Citizen science has been broadly defined, with projects varying widely in participation capacity, participation design, and project goals. Explicit references to citizen science began in the early 1990's within the context of environmental policy (Irwin 1995), where citizens played a role in knowledge production and advocacy. In the modern context, citizen science can range in scope and engagement. Towards the greater-engagement end of the spectrum, participatory action research projects (Cooper et al. 2007) are initiated by non-scientist members of the public and developed hand-in-hand with scientists or scientists hired by the project as consultants. Co-created, action type citizen science projects, (e.x., ReClam the Bay and Shermans Creek Conservation), are partnerships between local citizens and scientists. These types of projects have been successful in preservation and restoration efforts, similar to the more 1990's context of citizen science/activist projects. Toward the lesser-engagement end of the spectrum, contributory citizen science is a top-down model where researchers gather large amounts of data from a large number of citizen participants (see Wiggins and Crowston 2011 and Shirk et al. 2012 for modes of contribution overview). Regardless of the project type, all citizen science programs have participants engaged in authentic scientific research.

Benefits of Citizen Science

Citizen science has been found to be a useful tool for gathering large quantities of information, and has been shown to be effective in increasing scientific literacy for its participants (Bonney et al. 2009, Silvertown 2009, Dickinson et al. 2010). Citizen science programs have found increased participant knowledge (Jordan et al. 2011), increased civic awareness and engagement (Nerbonne and Nelson 2004), and increased participant engagement in scientific thinking (Trumbull et al. 2000). While many scientists or professionals engaging in citizen science explicitly include education and issue awareness goals for their participants (Crall et al. 2013), project participants frequently show knowledge gains and issue awareness of project participants by simply engaging in the project even if education was not an explicit goal (Nerbonne and Nelson 2004).

Crowdsourcing

While there are many unique definitions of crowdsourcing, it has been broadly defined as distributed problem-solving where a crowd of undetermined size is recruited to contribute (Chatzimilioudis et al. 2012). In a recent effort to develop an integrative definition of crowdsourcing, Estellés-Arolas and Ladrón-de-Guevara (2011) defined crowdsourcing as "a type of participative online activity in which an individual, organization, or company with enough means proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task." Researchers engaging individuals in this more traditional sense of crowdsourcing, like projects such as Perfect Pitch Test (perfectpitch.freehostia.com) and The Smell Experience (psych-institute.med.nyu.edu), allow researchers access to large numbers of participants to bolster sample sizes and increase sample heterogeneity. Additionally, crowd sourcing used in health research studies has had a broad influence on research outcomes and increased levels of scientific rigor (Swan 2012).

Benefits of Crowdsourcing

In the ecological and biological disciplines, for example, crowdsourcing has allowed scientists to successfully track various ecological phenomena, such as invasive species, on a global scale (Newell et al. 2012). These projects have used both active and passive crowdsourcing efforts, where the data were collected from participant input as well as photo-mining through social media sites such as Flickr and Twitter. While not often studied, crowdsourced projects have been shown to increase understanding of scientific information (Masters et al. 2016). Beyond research and learning, crowdsourcing has played a pivotal role in disaster relief and post disaster impact evaluation, as individuals can use social media platforms to both post information about the disaster and the impact to their surroundings in real time (Gao et al. 2011).

Citizen Science and Crowdsourcing

Both citizen science and crowdsourcing projects have resulted in the advancement of science while providing some, if only minimal, benefit to the participants. Indeed citizen science and crowdsourcing share many similarities across the literature. As previously mentioned, many citizen science projects are contributory (i.e., traditional citizen science model), which is similar to crowdsourcing. In fact, some projects have been referred to as being crowdsourced citizen science. Crowdsourcing citizen science projects capitalize on large numbers of participants to do work for free, often by 'gamifying' the way in which individuals participate (Good and Su 2013). The crossover between citizen science and crowdsourcing has become more apparent over time, where recent work has acknowledged the synonymous use of citizen science and crowdsourcing (Swan 2012). This fusion may be because of the imprecise and malleable definitions of citizen science and crowdsourcing. However, it cannot be assumed that, despite the similarities, the outcomes for participants of these projects are analogous. While there has been some work investigating participant outcomes for individual projects, there is a continuous lack of rigorous investigation of the mechanistic underpinnings that can drive or influence these outcomes. Additionally, practitioners using public participatory research in their work do not often attend to project design or program evaluation as a part of project development.

Recognizing that the activities of citizen science, particularly contributory citizen science and crowdsourcing can often be quite similar, we ask whether the framing of crowdsourcing or citizen science is a potential causal mechanism in the differences reported in participant outcomes between these project types. The work in this paper is couched in the context of climate change induced changes in phenology, which, in this project, refers to the timing of buds and flowers. We use climate change as the context of our study because of the ubiquity of this issue. Climate change has been described as a "wicked problem" (Levin et al. 2012); involving much complexity, which in many cases, has scientists struggling to obtain enough data. Additionally, climate change is an environmental issue about which the public struggles with the science. Finally, climate change information is highly subject to politicization and is therefore presented with many frames in the media. Biological phenomena such as phenology (described below) are often used to track planetary change.

Climate change challenges peoples' understandings because 1) it is spatially and temporally vast 2) it entails varying levels of uncertainty and 3) it has been highly politicized. Climate change occurs over long periods of time (lifetimes) and space (globally). This timescale is beyond human experiential knowledge so they often rely on short-term weather fluctuations to build their understanding of change (Donner and McDaniels 2013). Additionally, while there is always variability and scientific uncertainty in data and data projections, there has been an active media campaign to highlight specifically the uncertainties in climate science and question climate change's existence and potential impacts (Zehr 2000, McCright and Dunlap 2011). Last, because of the politicization of climate change, it has become increasingly apparent that one's orientation toward government intervention (measured as either Republican vs. Democrat or conservative vs. liberal) influences belief in the climate change science (Dietz et al. 2007, Hamilton 2011).

Framing trust and motivation

Framing is a term often used in the social sciences to refer to narratives that communicate information and why it matters (see Nisbet 2009 for a discussion). Framing scientific information is often an effective means to shape the public response to such ideas (Scheufele 1999) and often can be motivating. Academics and professionals have long acknowledged framing as a powerful tool and asset when addressing issues within the sciences and to the public at large (Wiederhold 2011). Framing can promote certain interpretations, evaluations, and solutions by emphasizing particular facets of an event or issue (Entman 2004). Frames also help to simplify complex issues by placing greater weight on some considerations and arguments rather than others, showing why an issue might be a problem, who or what might be responsible, and what should be done. Frames can provide common reference points and meaning between experts, the media, and the public (Groffman et al. 2010). A powerful example of framing was offered by scientist EO Wilson (2006), who partnered with evangelical Christian leaders, reframed the discussion of environmental stewardship in terms of morality and ethics. In reframing, Wilson is engaging an audience that might not attend to climate change issues because of the scientific foundation (Groffman et al. 2010). We suggest that framing also plays an important role in decisions about participation.

Objectives

In this work, we test whether a difference in project frame for the same activities can result in differences among participants' motivation, data collection, and views/trust of science. Through this intentional investigation of the mechanistic underpinnings that can drive or influence participant outcomes, we seek to stimulate further rigorous research about best practices in engaging the public in scientific research. Additionally, this work can help guide practitioners using public participatory research in their work in thinking about design and program evaluation as a part of their project development.

METHODS

To help create the frames, the authors needed to identify the major idea elements that make up the frames of crowdsourcing and citizen science projects. While there is acknowledged overlap between the project types, the authors conducted a qualitative interpretive content analysis to identify major frame elements. Qualitative interpretive analyses are used to identify and describe frames (e.g., Hoerl et al. 2009), often by identifying idea elements within those frames. To do this, the authors independently evaluated the websites of the major crowdsourcing and online contributory citizen science projects to identify unique idea elements and found four common major frame elements. The authors then looked in the existing scientific literature on project design and participation of the two areas to see if there was broader evidence supporting these notions (see Table 1). While this is not an exhaustive interpretive analysis, the internal consistency between the authors' independent evaluations and supporting literature suggest that this work is a valid first step towards investigating the impacts of framing

Given the large body of phenology-climate change literature and the existence of a well-known citizen science tree program, we devised tasks focused on tree phenology. The phenology, or life cycle variations of plant and animals, of various flora and fauna has been used as indicators of climatic changes. Observations of phenological variation such as earlier migrations and blooming have matched patterns predicted by global warming in the Northern Hemisphere (Schwartz et al. 2006). Such changes have been linked to a destabilization of certain ecological systems and a shift of organism interaction with their environment (Huete et al. 2006). Additionally, there is evidence of phenological shifts in the United States and Europe using trees and birds as indicators of climate change (Morin et al. 2008, Chen et al. 2011). Such shifts in plant species can also be linked to lengthened allergy season. Given the large body of literature on ornamental tree phenology (budding and range shifts), the tasks of participants will be exclusively focused on tree flowering and leaf drop. To assess phenology changes, participants will be able to compare their data to accounts of species, available through the National Phenology Network (http://www.usanpn.org).

Common Methods Between Citizen Science and Crowdsource Frames

Participants for each site were recruited separately and compensated equally for completing tasks. Individuals who participated in one participatory platform (e.g. crowdsourcing) were not allowed to participate in the other (e.g. citizen science). The tasks between these two participatory platforms were the same to standardize participant effort. The online web platforms were hosted through online domain free-ware. Individuals were recruited from Amazon Mechanical Turk (MTurk hereto forth) to allow the authors to hold participation motivation constant (all participants were being paid equally for their contributions) and therefore can attribute the differences to the modified framing elements alone. Participants were recruited in the spring of 2015 and fall of 2015 restricted to the Northeast region of the United States (New Jersey, Pennsylvania, New York, Massachusetts, Rhode Island, Connecticut, Vermont, New Hampshire, and Maine). This allowed for comparison of participant contributed data to actual phonological data. Participation occurred over the span of up to one week in either the spring or the fall, with individuals having 6 days after taking the pre-survey to submit data and take the post-survey. Information by participants will be used to assign each participant a likelihood of accuracy score to provide a sense of participant effort and achievement. For example, if a person stated that they were looking at a particular tree and then provided a photo of a grass, that participant was given a low value. A low value can also come from incomplete information. High values, however, were given for more accurate data and complete data forms. Participants were not made aware of these values. Only data from participants who completed the pre and post survey along with the tasks successfully (high-scoring participants) were used. Attrition rate from the project was calculated as those participants who did not complete the total number of tasks in relation to those participants who completed all the tasks.

The data collection procedure consisted of: (1) creating an anonymous ID for the project; (2) taking a pre-survey before entering the site; (3) exploring the website and information on it; (4) taking a picture of a flowering/budding (spring) or leaf color change (fall) tree in their area; (5) collecting information about the tree location, date, and the type of tree using a simple guide from the site; (6) posting the picture and submit the information on the website data form; (7) taking a post-survey about their experiences. Participants were also given the option to have their data submitted to Project Bud Burst to allow for participants to know that they collected scientifically meaningful data. The data submitted by participants allowed us to create a distribution map of tree budding and leaf drop by tree type and date that could be passed onto Project Bud Burst.

The pre and post participation questionnaires were taken within a week in mid-spring or mid-fall (see full survey in appendix). The pre questionnaire was used for project entry and asked demographic information (i.e., gender, age range, education, and technology comfort level). In addition the pre-to-post participation questionnaire included scales that address the following: Trust of science (T); Views of Science (VS); Motivation to contribute/ Identity (I); Views of citizen science (CS); and Science Literacy (SL). The post participation questionnaire only became available directly after participants submitted their tree data. The post participation questionnaire, in addition to the scales from the pre-questionnaire, contained the additional items to investigate any emergent differences between the framing interventions on project engagement (e.g., trust of project developers and data (3 items); ideas about scientific practices; motivation to contribute and project enjoyment (5 items)). The post questionnaire and the data submission options were given prior to distribution of MTurk $5 compensation. After compensation, a debriefing statement about their participation was provided.

Differences between the Citizen Science and Crowdsourcing Frames

While the task of all participants remained the same, the rhetoric and the layout of the online interface differed for participants. Since both contributory citizen science and crowdsourcing work through similar mechanisms of participant contribution and interaction, the framing of those contributions would be the expected trigger for different participant valuation of their contributions (Figure 1). In particular, project framing was altered on the components of rhetoric, participation goals, and the interface (see Table 2). All data were analyzed using R Studio.

RESULTS

Participant retentions for citizen science and crowdsourcing projects were calculated using combined participant data from the spring and fall data collection periods. For the citizen science frame there was a 65% rate of project completion with 91 individuals beginning the project and 59 completed paired pre/post/data submissions. Of those 59 completed, 49 of those had a high score to be retained for data analysis. For the crowdsource frame there was a 59% rate of project completion with 111 individuals beginning the project and 66 completed pre/post/data submissions. Of those 66 completed, 39 of those had a high score to be retained for data analysis. There were slightly different numbers of individuals starting the two different projects because individuals could accept the project (HIT) through MTurk without starting the program and there was a maximum number of HITs available. Because of the two time period sampling design, a Mann-Whitney U test was performed to compare the spring and fall data within the citizen science and crowdsource frames to test for differences related to the time of year the individual participated. A Mann-Whitney U is a non-parametric of the null-hypothesis that two samples come from the same population without the assumption of a normal distribution. No significant differences were found between the spring and fall data in either citizen science or crowdsourcing, allowing us to treat the fall and spring data as a single population.

To compare the effect of frame on participant outcomes a MANOVA was performed (post-post comparison) and revealed a significant multivariate main effect for the framing treatment (citizen science versus crowdsource) $F(1,94)=1.79$; $p=0.007$; Wilk's $\Lambda = 0.512$. Within the framing treatment there were a number of significant pairwise differences between variables (see Table 2). The survey items that showed up as significant in the pairwise comparison were in the areas of trust (T), views of citizen science (CS), views of science (VS) and identity (I). Because of the significance within these particular items within these areas of the survey, we did a pre-to-post comparison within each frame (citizen science and crowdsource) of specific items. A Wilcoxson signed-rank test was performed on the select items highlighted by the MANOVA on the pre-to-post data for both frames. The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test used when comparing two related samples, matched samples, or repeated measurements on a single sample to assess whether their population mean ranks differ (i.e. it is a paired difference test). There was a significant difference found pre-to-post in the citizen science frame of three particular items, but no difference pre-to-post in the crowdsource frame (see Table 3). Individuals who participated in the citizen science frame were more likely to agree that they should not trust corporate research, believe that scientific knowledge cannot be completely certain, and like to see their contributed information being used as a part of a larger data set post-participation.

DISCUSSION

These results suggest that there are differences in participant outcomes as a result of how projects are framed, even if everything else is held constant. The small differences made in this experiment between the two platforms (i.e., visual representation of the platform participants interface with and language about the role of the participant) significantly influenced participant outcomes. From the pre-survey, individuals in the citizen science and crowdsource frame had similar views in all areas of the survey, while post-participation we see significant differences emerge in many areas between the two frames. Particularly we found individuals who participated in the citizen science framed project shifted their responses in terms of their views of science, views of citizen science, identity, and trust. Citizen science participants were more likely to think corporate research is less biased, citizen science is a means of cheap labor, scientists generally agree on basic scientific concepts, and believe scientists are creative. Citizen science participants were also less likely to think observations solely support ideas rather than prove, less likely to enjoy reading about science, and less likely to enjoy logging information about hobbies. This is not to say that the majority of individuals who participated in either frame came away with negative views of citizen science or science in general, but that participating in this experience had a significant enough impact to differentiate their views post-participation. This could perhaps be attributed to citizen scientists having been presented with the 'scientist' perspective of the research, had the opportunity to grapple with those concepts, and challenge their own prior ideas. On the other hand, crowdsourcers were exposed to less of the "scientist perspective," thus maybe less likely to say certain things about science and scientists because it was framed as a fun endeavor, not necessarily a purely scientific endeavor.

What is also interesting is the lack of change in scientific literacy among either frame. The scientific literacy items represented almost a quarter of the total items asked on the questionnaire, but from the analysis there was no scientific literacy differences pre-to-post in either or between the two frames. Recent literature has suggested that simply the act of asking the public to collect and submit data may lead to successful broader public scientific literacy (Bonney et al. 2009), but perhaps this idea needs to be re-evaluated or caveated. Anecdotally, citizen scientists are a highly self-selected group of individuals and likely those individuals choosing to contribute to science on their own time are likely those already knowledgeable about and interested in science. Perhaps there are particular aspects about citizen science programs that can promote scientific literacy, but this has yet to be investigated in an intentional way. Additionally, participant enjoyment also did not fall out as different between the two frames, suggesting individuals enjoyed the tasks equally whether or not it was presented with a science heavy (e.g., citizen science) frame.

Given that crowdsourced projects can attract a large number of volunteers, we suggest that certain citizen science projects can borrow the broader, fun-oriented and socially enticing frame of many crowdsourced projects to encourage participation and that certain crowdsourced projects can borrow from citizen science an authentic view of data collection and evaluation practices to promote trust and science literacy. It is clear that technology plays an important role in many citizen science projects (Wiggins and Crowston 2011, Newman et al. 2012), particularly in terms of participant access, project management, and data submission. Indeed, intelligent use of technology can help overcome some of the difficulties in using citizen science in research. Citizen science project managers must ensure high data quality, while simultaneously making the project engaging and accessible to a wide range of participants, while increasingly demonstrating beneficial participant outcomes to granting agencies as a part of broader impacts. Having access to researched and vetted metrics of project design and development for these purposes would help practitioners tailor particular aspects of the project towards desired outcomes. These findings have broad implications for scientists hoping to engage the public in scientific research, particularly highlighting the importance of being mindful in the desired outcomes for participants and the mechanism of engagement.

The type of evaluation of citizen science done here is important to provide insight on the potential role as the common ground between the general public and the enterprise of science. Citizen science has been embraced by many disciplines, particularly in the biological sciences, with at current counts 1500+ published research articles citing the use of citizen science (Follett and Strezov 2015). Most of these articles tout the role of citizen science in communicating science and engendering a supportive public, but this rhetoric inherently assumes that every citizen science project has the same impact on participants. While there have been a few articles evaluating participant outcomes in citizen science programs, there has been little work investigating the mechanisms or components about these projects that is driving participant outcomes. This research is the first to the authors' knowledge that aims to evaluate if crowdsourcing and citizen science projects can be treated synonymously in terms of participant engagement and the role of framing these programs when discussing potential for public engagement and broader trust and literacy outcomes. Additionally, these results have broad implications to advance the state of the art in citizen science research, as project framing has little been addressed amongst citizen science researchers. Given the potential for citizen science activities to connect members of the public to science and scientific decision-making, best practices for citizen science as a field of inquiry should be sought with further studies investigating these links explicitly.

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Table 2.1 The four major frame elements and differences in framing between crowdsourcing and citizen science.

Frame Elements	Crowdsourcing	Citizen Science
Motivation for participation	Extrinsic: -fun or entertainment (Stewart et al. 2009, Wasko and Faraj 2000) -social rewards (Muhdi and Boutellier 2011, Stewart et al. 2009) -prizes or money (Hossain 2012, Leimeister et al. 2000)	Intrinsic: - learning or issue awareness (Brossard et al. 2005, Rotman et al. 2012, Tumbull et al. 2000) - doing-good or altruism (King and Lynch 1999, Silvertown 2009)
Rhetoric and Presentation to Participant	Fun Oriented (gameified): -designed for participants enjoyment (Good and Su 2013, Stewart et al. 2009) -goal of participation for participant is fun/money/social oriented (Kaufmann et al. 2011)	Science oriented: -science for the benefit of science/society/humanity/ (Bradford and Israel 2004) -goal of participation for participant is data collection (Cooper 2007, Dickinson et al. 2010)
Size of Project	Can have large numbers of participants: -e.x. CrowdSource (http://www.crowdsource.com) >500,000 participants	Tend to be fairly limited in participant numbers: -most projects only have tens of participants
Interface	Modern: -sleek design, aesthetically pleasing -prominent social media integration	Utilitarian: -design is not the forefront -science background and data submission

Table 2.2 Differences in the two frame element areas between the citizen science and crowdsourcing frame.

Frame	Crowdsourcing	Citizen Science
Rhetoric-Participation Goals	Externally regulated by physical incentives	On scientific advancement Internally motivated by self-achievement
Interface	Social media oriented, trends in Instagram/social photography	Utilitarian/ Data oriented

Table 2.3 Citizen Science vs. Crowdsource significant pairwise comparisons of post-post survey items.

	Sum Sq	Mean Sq	F value	Pr(>F)
Corporate research is almost always biased. (T) [Crwd]	5.829	5.8286	4.2297	0.04154 *
Citizen Science is basically a means to obtain cheap labor. (CS) [CitSci]	4.575	4.5754	6.3774	0.01265 *
Scientists generally agree on basic scientific concepts. (VS) [CitSci]	3.415	3.4153	4.6066	0.03354 *
Scientists commonly use creativity and imagination when conducting scientific investigations. (VS) [CitSci]	6.254	6.2538	8.5202	0.004081 **
Observations support rather than prove theories. (VS) [Crwd]	3.329	3.3286	4.5142	0.03533 *
I enjoy reading about science. (I) [Crwd]	1.684	1.68367	4.6107	0.03346 *
I think logging information about my hobbies is fun (e.g., miles ran, games won, recipes tried, etc.). (I) [Crwd]	3.329	3.3286	4.3017	0.03987 *

(T)=Trust; (CS)=Views of Citizen Science; (VS)= Views of Science; (I)= Identity
[CitSci]=Citizen Science/[Crwd]=Crowdsourcing refers to which frame agrees more the statement
Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05

Table 2.4 Pre-to-Post comparisons within each frame.

CrowdSource Frame		
I do not like learning about new things online. (-)	Identity (I)	(N=39, Z=2.35, p=0.01)
Citizen Science Frame		
Citizen Science is basically a means to obtain cheap labor. (-)	Views of Citizen Science (CS)	(N=49, Z=1.97, p=0.048)
When I read a brochure provided by a company, the research in the brochure should not be trusted. (+)	Trust (T)	(N=49, Z=2.86, p=0.004)*
Scientific knowledge can never be completely certain. (+)	Views of Science (VS)	(N=49, Z=2.79, p=0.005)*
The goals of science are to improve society. (+)	Views of Science (VS)	(N=49, Z=1.89, p=0.05)
I like to see the information that I contribute being used as part of a larger data set. (+)	Identity (I)	(N=49, Z=2.50, p=0.008)*
Being an amateur scientist is cool. (+)	Identity (I)	(N=49, Z=2.40, p=0.01)

*Significant pre-to-post differences with adjusted alpha value.

Figure 2.1 Represents two frames to the single story about changing phenology. At the heart of the project, individuals collected information about a single tree and then had the opportunity to compare their information to larger trends regarding timing of flower emergence. The tools from the USA National Phenology Network (http://www.usanpg.org) aided in the provision of data trends and visualization. The top frame represents a citizen science model and the bottom frame represents a crowdsourcing model.

Chapter 3: A Case Study of Framing Ecological Issues: Zika Messaging and Disease Prevention

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Abstract

Ecological problems have recently been politicized and subject to misinformation campaigns to divide public belief and action on these issues. Given the urgent need to address this phenomenon, we suggest that desired public action can be motivated through intentional employment of framing in science communication. In this paper, we sought to evaluate the effect of framing about ZIKV (Zika virus) communication, by explicitly connecting two ideological congruent ideas (i.e., protecting self = protect others) for individuals, and measuring the potential shifts in resident behavior towards willingness to comply with mosquito prevention action. Post framing intervention, we found a significant increase ($N=26$, $p<0.001$) in individuals willing to take preventative action against mosquitoes. By methodically investigating best-practices in communication, this study and others, can help practitioners mobilize communities to address large-scale ecological problems. Additionally, the principles outlined here, connecting ideological congruent ideas, may be transferrable to other communication efforts.

In a Nutshell

-Principles from communication research have not been widely investigated in the context of ecological issues, particularly thinking about how practitioners communicate scientific issues to the public and the underlying mechanisms within those communication pieces driving public behavior change in response.

-This case study of how framing can influence public behavior, in the context of invasive mosquitoes, demonstrates that individuals are more compliant with disease prevention efforts after an intentionally crafted communication piece.

-Employing best-practices in science communication can help ecology researchers and practitioners create nuanced communication pieces to effectively engage with and influence public behavior and decision making.

Introduction

The Anthropocene (geological period, industrial revolution-present), is characterized by scholars as the time in which humans have had a disproportionate, often negative, impact on the earth's bio-physical systems (Crutzen and Stoermer 2000). Global climate change, arguably the major issue to emerge from human impact, has been linked as a driver, or aggravator, of many ecological problems (i.e., phenology shifts and mismatches, invasive species establishment, biodiversity loss). Beyond the bio-physical threats climate change poses, it has also been subject to politicization through active media campaign to highlight uncertainties in climate science to sow doubt of climate change's existence (Zehr 2000). This rampant politicization of science (Pielke 2002) makes engaging with local communities (Dolan et al. 2003) and persuasive science communication (McNutt 2013) increasingly important to address ecological problems.

One area that has been little explored in the ecological literature to address these issues of community engagement and persuasive communication is intentional employment of frame theory from the communication sciences. Framing, or frame theory, is a set of theoretical perspectives that focus on how individuals interpret and communicate reality (Goffman 1974). By employing frame theory, one can promote a particular interpretation or evaluation of events/issues by emphasizing particular facets of those events or issues over other facets (Nisbet and Mooney 2009). Framing and reframing scientific issues can help scientists find common ground with the public and build support for those issues (Nisbet and Mooney 2009). A recent study on the effect of framing in public support of environmental conservation, found that individuals' who identified as environmentalist ranked highly protecting the environment when it was framed "ecosystem services" versus those who did not identify as environmentalist ranked highly protecting the environment when it was framed as "environmental security" (Sorensen et al. 2015). E.O. Wilson's (2006) work with evangelical Christian leaders is another powerful example, in which environmental stewardship is reframed in terms of Christian morality. This work highlights how creating audience-specific frames around environmental conservation can engender broader public support for these types of issues. Indeed, framing has been successful in influencing public support and encouraging desirable actions regarding other politicized, hot-button scientific topics like vaccinations in the public health domain (McRee et al. 2010).

In the public health domains, individual decision-making has been plagued by misinformation campaigns (much like climate sciences), much of it based on false science published (Wakefield et al. 1998-retracted) in the 1990's. This has led to long-lasting negative impacts on vaccination rates (Freed et al. 2010) and public health communication (Flaherty 2011). Recently there has been extensive effort by scientists in the field to address this problem by employing framing and frame alignment to influence vaccination behavior. Broadly, frame alignment involves linking ideologically congruent ideas that are currently not connected and often amplifies currently held values by the individual (Snow et al. 1986). An example of frame alignment from the vaccination literature demonstrates that willingness to get a vaccine is greater if the framing focuses on positive health outcomes versus the risk of negative outcomes without a vaccine (Ferguson and Gallagher 2007). This type of frame alignment has been used extensively in the public health literature to increase vaccination compliance with great success

(Allen et al. 2010). Given these successes in the public health literature in employing framing, we argue these methods could also be applied to ecological issues as well.

Framing in Ecology

In order to explicitly investigate framing in an ecological context, the authors wanted to test these ideas in the context of a current issue. The invasive *Aedes* spp. mosquitoes and Zika virus (here-to-forth ZIKV) were used here as a case study of the efficacy of these ideas. This is an ideal system to test these ideas because (1) *Aedes spp.* mosquitoes are difficult to manage through mosquito control mechanisms without community participation (Unlu et al. 2011) requiring community action and engagement, (2) winter warming due to global climate change will continue to expand the effective range where Ae. albopictus can persist (Rochlin et al. 2013) making it a persistent issue, and (3) there has been a wide variety of ZIKV communication, often sensational (Rohde 2016), similar to prior examples in other science domains.

About ZIKV

ZIKV has become an international health threat, primarily because it has been associated with infant microcephaly when the mother is infected during pregnancy (Paploski et al. 2016). ZIKV has also been associated with Guillain-Barré syndrome and other neurological and autoimmune complications (Paploski et al. 2016). While *Aedes aegypti* is commonly cited as the main vector of ZIKV (Cao-Lormeau et al. 2014), the Asian Tiger Mosquito, *Aedes albopictus*, which is a public health threat in its own right (see Medlock et al. 2012 for review), is also a competent vector (Wong et al. 2013). The risk for ZIKV transmission is greatest in equatorial regions; however, the United States is also at risk in regions where either of the predominant *Aedes* (*aegypti or albopictus*) vectors are present.

Given the need to control potentially competent vectors of ZIKV, we suggest that community action to prevent the spread can be motivated through specialized framing around ZIKV communication to increase public compliance and preventative behaviors. Practitioners are seeking new approaches for *Aedes* mosquito control (beyond ditching, and broad application of adulticide and larvicide) as many of the previously developed mosquito control methods do not take into consideration the different life history and behavioral traits of *Aedes sp.*

Ae. albopictus is referred to as an urban mosquito because urban areas provide a plethora of container-breeding habitats, thus enabling high population densities. Many of these habitats are on private property (residential backyards, construction areas, condemned houses, etc.); making them inaccessible to mosquito control workers. *Ae. albopictus* is also commonly associated with low socioeconomic areas because juveniles readily develop in unmanaged containers that are more likely to accumulate in disadvantaged neighborhoods (LaDeau et al. 2013), though it can also persist in higher socioeconomic areas where residents have features that hold water (i.e., container gardens, bird baths) (Unlu et al. 2011). Additionally, a feedback loop can exist between the two socioeconomic areas where the breeding habitats in lower socioeconomic areas are eliminated or reduced, but high socioeconomic areas harbor pools of mosquitoes to recolonize (Unlu et al. 2011). In urban areas that are characterized by this type of feedback loop, it is particularly important to have compliance at the household level across neighborhoods.

Objectives of Study

In this paper, we sought to (1) evaluate the effect of current ZIKV communication framing on public behavior, (2) create frame alignment by explicitly connecting ideological congruent ideas (i.e., protecting self = protect others, breaking the transmission cycle), and (3) test for shifts in resident behavior towards willingness to comply with mosquito prevention action using the new frame. This work was carried out in West Baltimore, Maryland, USA because it is characterized by this relationship of closely intertwined high/low socioeconomic areas, making the residents the target audience for these types of interventions.

Methods

We used a multiple step approach to investigate how framing impacts resident behavior in West Baltimore. First, we established community perceptions of ZIKV risk and severity to investigate the efficacy of current communication materials and help build our alternative frame through a semi-structured interview with 60 people. Second, we conducted an initial frame analysis of the current ZIKV communication efforts in West Baltimore to identify common frame elements. Last, we report on an interview of our alternative frame created by findings from the first and second steps with 26 people, for communication about ZIKV and a pre/post questionnaire addressing resident behavior towards ZIKV and mosquitoes.

Establishing Community Perceptions of ZIKV

We opportunistically sampled the population of residents in four local parks, making two site visits per park during May and June 2016 until we had completed surveys with 15 non-pregnant people per park (60 surveys total). The survey was comprised of two Likert-like questions and one free-response question, taking each participant about 10 minutes to complete. All participants were compensated $5 for their time. For the two Likert-like questions, each respondent rated five diseases, four common to the Baltimore, MD region (common cold, food poisoning, flu, strep throat) that they could encounter in the coming year for perceived likelihood of infection and severity if they were infected. Sixty-one percent of respondents rated ZIKV as the most serious illness and felt that were as likely to get ZIKV as the other illnesses (See Table 1). Participants were then asked in free-response format about their ranking of ZIKV and their current behavior towards mosquitoes. From these responses, 73% of individuals did not know why ZIKV poses serious risks. When asked about their likelihood of infection, 80% identified the risk as being minimal and thought they could avoid infection. Only slightly more than half intended to protect themselves from ZIKV and, of those that did, very few were using effective strategies that would have an impact on their likelihood of being bitten by mosquitoes (i.e., strategies recommended by the Center for Disease Control). The CDC cites effective strategies of ZIKV prevention as: using mosquito repellant when outside, taking precautions or avoiding travel in known infested areas, covering up with clothing, and reducing mosquito breeding habitat. Strategies individuals reported using to protect against ZIKV included; swatting the mosquitoes when they saw one land on them, smoking to deter mosquitoes, spraying the mosquitoes with insect repellant, and not going outside when they believed mosquitoes were out. Though the seriousness of this illness is high, it was clear that the respondents were relying on not being one of the persons becoming infected. We believe that individuals do not have an informed sense of risk, especially as related to preventive action.

Additionally, no participants were able to describe a typical symptom of ZIKV infection. Many reported they felt that because alarm was so high both for pregnant and non-pregnant persons, symptoms of the illness were quite serious for all people. All were unaware that most individuals who get ZIKV do not experience symptoms (Symptoms), and therefore do not know they could be contributing to the spread. The notion that personal action and protection would help prevent the spread of the virus to others was underappreciated. Further, the idea that ZIKV is most serious for vulnerable populations (e.g., pregnant persons), and most will not know that they are infected seemed entirely discounted. Based on our conversations, framing communication about ZIKV by encouraging prevention as a means of protecting others (i.e., breaking the transmission cycle) encourages an alternative perspective on health and behavioral management. Indeed, this shared responsibility frame has been shown to be effective for increasing vaccination compliance (Vietri et al. 2012). Given that the need for mosquito control is important beyond the individual's needs, much like vaccines, we argue that reframing to a shared responsibility messaging may increase compliance.

Current ZIKV Communication Frame

Frame analysis is often characterized as the way in which scientists or researchers tease apart the processes or ways in which a frame is presented in communication (Devereux

2007). We evaluated the communication materials on ZIKV (flyers, pamphlets, information on websites, billboards, etc.) published by the CDC and the DHMH (Maryland Department of Health and Mental Hygiene) to which residents of Baltimore were likely exposed. In this evaluation, we aimed to establish what the dominant frame valance of ZIKV communication is for this region. We used the content analysis procedures developed by Matthes and Kohring (2008) by coding the different frame elements of the major communication materials. The analysis identified a single dominant frame valance of “personal safety” or “individual action” (see Table 2) in these communication materials. In this frame, the emphasis for protecting against ZIKV is to prevent the individual from getting the virus. This frame is congruent with the findings from the survey mentioned earlier where individuals felt that getting ZIKV was very severe and dangerous for them, regardless of whether or not they were part of the vulnerable population. What is missing in this messaging is the notion that an individual protecting oneself, helps to prevent others from getting ZIKV.

New ZIKV Frames

In our framing we wanted to connect these two ideological congruent ideas (i.e., protecting self in order to protect others, breaking the transmission cycle). To do so, we incorporated frame alignment theory (Snow et al. 1986) where we explicitly connect communication about ZIKV prevention to commonly held beliefs and values (i.e., protecting mothers and babies). Our frame of ZIKV communication focuses on a “collective action” frame valance, where the burden of protecting unborn babies from ZIKV is the responsibility of each individual (see Table 3). We hypothesized that by explicitly changing the frame valance from a “personal safety” to “collective action,” individuals will report greater willingness and compliance in taking action to protect oneself against ZIKV.

Procedure and Materials

The intervention was broken down into three parts to test whether our framing of ZIKV and mosquito information affected behavior: a pre-survey, the framed narrative, and a post-interview. In the pre-survey, participants were asked if they had experienced communication efforts about ZIKV recently and whether they currently take action to prevent mosquito bites and ZIKV (2 binary items). Participants were then read a brief narrative created with the "collective action" frame valance by the researchers. In this narrative, preventing ZIKV was discussed as a collective action with an emphasis on breaking the transmission cycle (see Table 4 for frame comparison). In the post-intervention interview, individuals were asked if they would now take action to prevent themselves from getting ZIKV (1 binary item), and in free-response format, connect how their action would help pregnant women and unborn babies. All interview and narrative materials can be accessed in Appendix 3. A McNemar test was used to test the effect of the intervention. All statistical analyses were performed in SPSS Statistical software (Version 22.0).

Results

Participants

All respondents (N=26) were residents from West Baltimore, Maryland surveyed over 3 months (July, August, September) in 2016 when they were most likely to be exposed to

ZIKV information. Some of the respondents (*n*=12) were recruited from a local, multi-year mosquito citizen science program that worked with residents in four neighborhoods of West Baltimore. The rest (*n*=14) of the respondents were recruited locally from parks within these four neighborhoods but were not affiliated with the citizen science program. To ensure that there were no significant differences between the two sample populations and any outcomes were due to the framing intervention, a students t-test was performed on the pre-framing interview responses. We found that there was no significant difference (N = 26, t=-0.596, p=0.278) in responses regarding compliance with personal mosquito protection between the sample populations prior to the framing intervention, allowing us to treat this as one sample population.

From the pre-interview, of our 26 respondents, 3 reported that they were already taking preventative action to protect themselves from mosquito bites. Post framing intervention, we found a significant shift in respondents' reported behaviors (N=26, $p<0.001$). Nineteen of the 23 who prior were not protecting themselves from mosquitoes, reported they were going to take action after the intervention. Four reported they would not take action to protect themselves against ZIKV before or after the intervention. The intervention did not affect the three individuals who were already taking action to protect themselves, reporting they would continue to do so.

To probe further about the respondents understanding of why their actions to protect themselves against ZIKV would be help the broader community, participants were asked a free-response follow up question, "How does your taking care to avoid the Zika virus help those who are pregnant?" Because a part of the framing intervention narrative was explicitly linking self-protection to protection of others, we expected all participants to be able to connect these ideas in their response. We evaluated and coded participant responses for inclusion of direct or indirect reference to individual action having broader positive impacts. Of the 26 respondents, 12 referenced some aspect of their individual behavior benefiting others (e.x., "*protecting myself will help prevent babies being born with problems*", "*fewer mosquitoes carrying the virus if I don't get the virus*"). 13 respondents did not connect the ideas that their own behavior can have broader effects and emphasized self-protection alone (e.x., "*all women should have bug spray*", "*I will avoid mosquitoes so I don't get sick*"). One individual believed that his/her actions would have no effect and thus he/she could not protect him/herself, or others, from ZIKV.

Discussion

This research suggests that resident behavior towards ZIKV, and more broadly towards *Ae. albopictus,* can be influenced through simple reframing of current communication. Particularly, in explicitly connecting the two ideological congruent ideas (i.e., protecting self= protect others, breaking the transmission cycle) for individuals, we see significantly increased willingness to comply with mosquito prevention. It is clear that new methods and strategies are needed to address this problem, one of which being collective action by local communities. The results of this study, in considering best practices in communication strategies, can help practitioners mobilize communities to take action. Participants, despite not all being able to explicitly connect their behavior to protection of vulnerable populations, still reported being willing to take action after the framing intervention. This suggests that it may not be necessary for the broader public to understand the mechanisms behind how their actions will help protect vulnerable persons, as long as it is made clear in the communication that it does.

While the authors have taken the first steps in establishing efficacy of employing framing in ecological issue communication, the long-term impacts of this framing intervention on behavior need to be investigated further. It is unknown whether this type of intervention will promote longitudinal behavioral changes. Consideration of the frequency and timing of this type of tailored messaging is likely also influential in promoting sustained behavior change. This work brings new insight for practitioners seeking to address complex ecological problems in communities and comes at a point when best practices in communication and public engagement in all realms of science need further development.

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Table 3.1 Survey respondents (N=60) ranked their perceived seriousness and likelihood of getting of following illnesses within the next year, 1 being most serious/likely and 4 being least serious/likely. Scores below represent the mean rank and the standard deviation.

Illness	**Serious** Mean (std.dev.)	**Likely** Mean (std.dev.)
Zika Virus	1.5 (0.84)	3.0 (0.77)
Common Cold	2.9 (1.10)	2.7 (0.99)
Flu	2.1 (0.98)	2.9 (0.84)
Food Poisoning	2.0 (0.99)	2.9 (0.87)
Strep Throat	2.1 (0.94)	3.0 (0.77)

Table 3.2 Frame elements and variables in current Zika virus communication put forth by CDC and other governmental organizations. The "personal safety" frame.

Frame Elements	*Variables*
Topic/Theme	Mosquito control
	Individual action for individual prevention- personal safety
Actor	Individuals
Benefit	Reduced Zika virus for self
Benefit Attribution	Reduced mosquito populations lead to reduced Zika load
Risk	Spread of Zika virus
Risk Attribution	Lack of current effective mosquito control in urbanized areas
Solution	Individual protection and reduce mosquito populations
Proponent	Center for Disease Control and other Governmental agencies
Treatment	Neutral/ Negative

Table 3.3 Frame elements and variables in our re-frame of Zika virus communication. The "collective action" frame.

Frame Elements	*Variables*
Topic/Theme	Breaking transmission cycle
	Individual action for group benefit- public wellbeing
Actor	Local community organizations
	Individuals
Benefit	Reduced Zika virus in the community
Benefit Attribution	Breaking the transmission cycle
Risk	Spread of Zika virus
Risk Attribution	Individuals in community may be infected with Zika virus but are unaware
Solution	Collective action to protect vulnerable populations against Zika virus and in mosquito control
Proponent	Academia (at current)
	CDC and other governmental organizations
Treatment	Positive

Table 3.4 A comparison of the two frames as was presented to survey participants. Highlights the key areas of emphasis that differed between.

Individual Action Frame	Collective Action Frame
-Current communication frame.	-Proposed communication frame.
-Individual preventative behaviors benefit self.	-Individual preventative behaviors benefit others.
-Focus on illness and effects of Zika on the individual.	-Focus on illness and effects of Zika on pregnant women and unborn babies.
-Reducing mosquito populations will reduce Zika virus load in communities.	-Breaking transmission cycle will reduce Zika virus load in communities.

Conclusions

This work strongly suggests that framing plays an important role in how communicating messages about the environment, and climate change in particular, impacts how members of the general public perceive those issues. Additionally, framing can also drive behavior of target audiences, which is important in addressing these types of issues.

In the first chapter, I found that individuals who self-identified as environmentalist were positively associated with ranking most important environmental conservation when it was framed as either environmental quality or ecosystem services, but not when it was framed as environmental security. Conversely, those individuals who did not rank themselves highly as self-identified environmentalists were positively associated with environmental conservation when it was framed as environmental security. This research suggests that changing a simple word frame can change audience opinion on an issue, even hot-button issues like climate change. In the second chapter, I found after participation there was indeed significant differences in participant outcomes between frames (as citizen science versus crowdsourcing), even though individuals were engaged in the same task. This work can help guide practitioners using public participatory research in thinking about program design, participant recruitment, retention and views about outcomes. In the third chapter, I found after being exposed to an alternatively framed communication piece about Zika virus, there was a significant increase in individuals willing to take preventative action against mosquitoes. This suggests that a change in frame not only results in different perceptions, but also in behavior. In this case, these perception and behavior changes likely improve ecological and health outcomes for the community. By methodically investigating best-practices in framing communication, this study and others, can help practitioners mobilize communities to address large-scale ecological problems. Additionally, the principles outlined in this chapter, connecting ideological congruent ideas, may be transferrable to other communication efforts.

The results from the work presented here have broad implications for communication and public engagement practices by scientists around ecological issues. While scientists and practitioners have little control over politically-drive misinformation campaigns about climate change and other domains of science, research such as this can help guide public communication efforts for maximum efficacy.

Appendix 1

Survey Items:

Views on the nature of science items

	Never	Occasionally	Half the time	Often	Very often
a) How often do scientific theories need to be based on data that are visible to the human eye (either the naked eye or with the aid of microscopes, telescopes, etc.)?	1	2	3	4	5
b) How often do scientists need to use experiments to determine if something is true?	1	2	3	4	5
c) Good scientific experiments need a laboratory environment.	1	2	3	4	5

Framing Items

Rank in order from 1 to 10 the issues you believe Americans should be making effort to fix. 1 being the issue that should have the most effort, down to 10 with the issue needing the least effort.

_______ Curing cancer.

_______ Improving the quality of our environment.

_______ Improving environmental security.

_______ Improving the quality of US education.

_______ Decreasing crime and drug use.

_______ Reducing heath care costs.

_______ Decreasing poverty.

_______ Growing the US economy.

_______ Reducing the budget deficit.

_______ Improving ecosystem services.

Environmental Belief Items

Using a scale of 1 (strongly agree) to 4 (strongly disagree), please rate the extent to which you agree or disagree with the following.

	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree
a) I do not have the knowledge to understand most environmental problems.	1	2	3	4
b) I am confused about what is good and what is bad for the environment.	1	2	3	4
c) I consider myself an environmentalist.	1	2	3	4
d) Most environmental problems can be fixed later.	1	2	3	4

Environmental Knowledge Items

What is the most common cause of pollution of streams, rivers, and oceans? It is…

a. Dumping of garbage by cities
b. Surface water running off yards, city streets, paved lots, and farm fields
c. Trash washed into the ocean from beaches
d. Waste dumped by factories
e. Don't know

How is most of the electricity in the U.S. generated? It is…

a. Burning oil, coal, and wood
b. Nuclear Power
c. Solar Energy
d. Hydro Electric Power
e. Don't know

What is the most common reason that an animal species becomes extinct? It is because…

a. Pesticides are killing them
b. Their habitats are being destroyed by humans
c. There is too much hunting
d. There are climate changes that affect them
e. Don't know

Scientists have not determined the best solution for disposing of nuclear waste. In the U.S., what do we do with it now? Do we…

a. Use is as nuclear fuel
b. Sell it to other countries
c. Dump it in landfills
d. Store and monitor the waste
e. Don't know

Which of the following is a renewable resource? It is…

a. Oil b. Iron Ore c. Trees d. Coal e. Don't know

Appendix 2

Demographic Information (4 items, Pre-survey Only)	Rationale
What year were you born in? Which gender do you identify with? What is your annual household income? What is highest level of education you have obtained?	Demographic variables about respondents that may comprise or influence an individuals' identity. Also asked to ensure respondents were from our target demographic.
Technology Comfort Level (7 items, Pre-survey Only)	
Technology is important to human life. I do NOT want to spend much time working with technology. I am comfortable using new technology. My life relies heavily on technology. I find new technology exciting. I am terrible at figuring out technological problems. I am comfortable providing information to website I think are trustworthy.	Technology questions were asked to gauge participant comfort with technology and whether interest in and comfort with technology was a factor driving participant engagement.
Trust of Science (8 items) [T]	
The purpose of research is to enable a better society Scientists are generally trustworthy As long as the researcher is a trained professional, the research conducted is reliable Research most often serves special interests. Corporate research is almost always biased Research about climate change is biased. When news outlets provide press releases about science, these releases are generally trustworthy. When I read a brochure provided by a company, the research in the brochure should not be trusted.	Trust of science questions were used to establish baseline participant views about science. These items were also asked in the post-survey to establish differences in trust of science due to citizen science or crowdsourcing participation and allow for pre-to-post comparison.
Views of Science (9 items) [VS]	
The goals of science are to improve society. Scientific knowledge can never be completely certain. Two scientists could make the same observation of an event and research different conclusions. Scientists generally agree on basic scientific concepts. Reliable scientific claims can be uncertain. Scientists who conduct scientific research can be influenced by their race, gender, nationality, or religion. Scientific practice is influenced by culture and society. Creativity is important for the growth of scientific knowledge. Creative thinking and imagination are NOT important to the field of science. Scientists commonly use creativity and imagination when conduction scientific investigations.	Views of the Nature of Science (VNOS) questionnaire items were asked to establish baseline views of the practice of science amongst participants. These items were also asked in the post-survey to establish differences in views of science due to citizen science or crowdsourcing participation and allow for pre-to-post comparison.
Post-Participation Views of Science (3 items) (Post-survey only)	
I would trust data produced from this study. The information that I provided will serve the greater good. The individuals who designed this study simply want to promote the ideas that they already have.	These items addressed participants' views of science and their contributions in the context of this study.
Views of Citizen Science (2 items) [CS]	
Data contributed by non-professionals (e.g. citizen scientists) is never as good as data collected by professionals. Citizen science is basically a means to obtain cheap labor.	These items addressed participants' opinions about citizen science specifically.

Science Literacy (15 items) [SL]	
Scientific theories are durable and do not change over time. Scientific theories can change with new evidence. Scientific theories can change with new ways of looking at old evidence. No form of knowledge -including science- can ever be completely objective. When conducting scientific investigations, personal bias, preference, and opinions of scientists play no role. Observations support rather than prove theories. Scientific knowledge is subject to review by other scientists. Scientists use a universal step-by-step method for conducting scientific investigations. Experiments are not the only way to conduct scientific investigations. Scientific theories need to be based on data that are visible to the human eye (either the naked eye or with the aid of microscopes, telescopes, etc.) Scientists need to use experiments to determine if something is true. Good scientific experiments need a highly controlled environment. Science is primarily concerned with understanding how the natural world works. Scientific knowledge builds on earlier knowledge. Some questions cannot be answered by science	Scientific literacy items were asked to address whether there were significant gains in scientific literacy pre-to-post among participants. Citizen science has been attributed in the literature to help promote and increase scientific literacy among its participants. These items sought to address those claims and investigate whether framing affected those outcomes.
Identity (16 items) [I]	
I enjoy reading about science. I do not enjoy collecting data. I enjoy surfing the web. I do not like learning about new things online. I am always online. I think logging information about my hobbies is fun (e.g., miles ran, games won, recipes tried, etc.) Public contribution to knowledge on the internet is a great idea. Sharing data with corporate sponsors will help make better products geared to my needs. I hate the thought of providing my personal information to public websites. I contribute material online only if I am promised a product or money. I like to see the information that I contribute being used as a part of a larger data set. I like to track online information over time. I have much to contribute to science. Being an amateur scientist is cool. When I provide information online, I am making a valuable contribution to society.	Identity items were used to investigate the motivations and characteristics of individuals who participate in these types of programs. Particularly, looking at prior interest in science and logging/sharing information as these types of projects often require.
Project Enjoyment (5 items, Post-survey Only)	
To what extent did you enjoy participation in this project? To what extent do you feel you learned new material from participation in this project? To what extent did your participation in this project matter with respect to the larger dataset? To what extent has you attitude toward your personal role in contributing to science changed as a result of participating in this project? To what extent do you feel participating in this project was a benefit to you?	Project enjoyment items were used to investigate whether framing affected how participants felt after participating. Did the crowdsourcers enjoy the task more or less that the citizen sciencers.

Appendix 3

Establishing Community Perceptions of ZIKV SURVEY

(Part of a larger survey published elsewhere).

Script: Assent for adults who participate (no name or identifying information is collected). You are being asked to participate in a research project. The purpose of our research is to find out about what you know about mosquitoes and science. The data you collect will be used as part of a Baltimore Area Mosquito Assessment Survey. Your participation will include receiving an anonymous code to be used on your pre-post survey about your beliefs (these are not right or wrong questions). Anonymous means that no personal identifying information is collected for the research. There are no risks or near-term benefits to your participation. In the long term, we hope to develop a mosquito control program. You can stop your participation at any time. You will receive monetary compensation for your data sheets, which will be handed to you as cash when you return your data. Do you understand what I am saying and are you willing participate in our project?

Q1. Things to make note of:
- ❍ Gender (1)
- ❍ Ethnicity/Race (2)
- ❍ Children (3)
- ❍ Age (4)

Now we would like to understand your impressions related to a few issues regarding trash and pest control.

The issues of trash and pest control highlighted above relate to the potential for zika virus spread. We will now ask questions specifically about zika virus.

Q2. What do you know about the following illnesses (focus on zika)? Listen and then score.

	Knowledgeable (1)	Moderately knowledgeable (2)	Knows a little (3)	Knows nothing (4)
A common cold (1)	❍	❍	❍	❍
The flu (2)	❍	❍	❍	❍
Food poisoning (3)	❍	❍	❍	❍
Zika virus (5)	❍	❍	❍	❍
Strep throat (6)	❍	❍	❍	❍

Q3. How serious would it be if you came down with one of the following illnesses.

	Very Serious (1)	Serious (2)	Not very serious (3)	Nothing to worry about (4)
A common cold (1)	❍	❍	❍	❍
The flu (2)	❍	❍	❍	❍
Food poisoning (3)	❍	❍	❍	❍
Zika virus (5)	❍	❍	❍	❍
Strep throat (6)	❍	❍	❍	❍

Q4. How likely is it that you would come down with one of the following illnesses.

	Very likely (1)	Likely (2)	Not very likely (3)	No chance at all. (4)
A common cold (1)	❍	❍	❍	❍
The flu (2)	❍	❍	❍	❍
Food poisoning (3)	❍	❍	❍	❍
Zika virus (5)	❍	❍	❍	❍
Strep throat (6)	❍	❍	❍	❍

Q5. How likely is it that people can take action against the following illnesses?

	Very likely (1)	Likely (2)	Not very likely (3)	No chance at all. (4)
A common cold (1)	❍	❍	❍	❍
The flu (2)	❍	❍	❍	❍
Food poisoning (3)	❍	❍	❍	❍
Zika virus (5)	❍	❍	❍	❍
Strep throat (6)	❍	❍	❍	❍

Q6. How likely is it that the government can take action against the following illnesses?

	Very likely (1)	Likely (2)	Not very likely (3)	No chance at all. (4)
A common cold (1)	❍	❍	❍	❍
The flu (2)	❍	❍	❍	❍
Food poisoning (3)	❍	❍	❍	❍
Zika virus (5)	❍	❍	❍	❍
Strep throat (6)	❍	❍	❍	❍

Q7. How likely is it that you will take action against the following illnesses?

	Very likely (1)	Likely (2)	Not very likely (3)	No chance at all. (4)
A common cold (1)	❍	❍	❍	❍
The flu (2)	❍	❍	❍	❍
Food poisoning (3)	❍	❍	❍	❍
Zika virus (5)	❍	❍	❍	❍
Strep throat (6)	❍	❍	❍	❍

Q8. Where do you get your information about preventing illnesses (ask about internet sources)

	Very often (1)	often (2)	Not very often (3)	Never (4)
Newspapers (1)	❍	❍	❍	❍
Television (2)	❍	❍	❍	❍
Radio (3)	❍	❍	❍	❍
Internet (4)	❍	❍	❍	❍
Your doctor (5)	❍	❍	❍	❍
Other people (6)	❍	❍	❍	❍
Other (7)	❍	❍	❍	❍

Q9. Where do you get your information about zika (ask about internet sources)

	Very often (1)	often (2)	Not very often (3)	Never (4)
Newspapers (1)	❍	❍	❍	❍
Television (2)	❍	❍	❍	❍
Radio (3)	❍	❍	❍	❍
Internet (4)	❍	❍	❍	❍
Your doctor (5)	❍	❍	❍	❍
Other people (6)	❍	❍	❍	❍
Other (7)	❍	❍	❍	❍

Q10. Do you plan on changing any of your behavior because of the zika virus threat?

❍ Definitely yes (1)
❍ Probably yes (2)
❍ Might or might not (3)
❍ Probably not (4)
❍ Definitely not (5)

Q11. If yes, what?

New ZIKV Frames MATERIALS

Script: Assent for adults who participate (no name or identifying information is collected). You are being asked to participate in a research project. The purpose of our research is to find out about what you know about mosquitoes and Zika virus. Your participation will include receiving an anonymous code (these are not right or wrong questions). Anonymous means that no personal identifying information is collected for the research. There are no risks or near-term benefits to your participation. In the long term, we hope to develop a mosquito control program. You can stop your participation at any time. You will receive monetary compensation for your responses at the end of the survey. Do you understand what I am saying and are you willing participate in our project?

Q1. Have you heard of zika virus?

YES_____ NO_____

Zika virus is likely to be introduced to this region of the United States and the Asian Tiger mosquito are able to transmit the virus to people if they become infected.

Q2. Are you currently doing anything to avoid the virus?

YES_____ NO_____

Zika is a serious threat. While many people with the virus will not fall ill, those that do may experience a rash/fever. It is because people often don't show symptoms that makes Zika hard to control. To avoid the spread of the virus, people should use mosquito repellent (as directed); especially when traveling to countries where Zika is being spread by mosquitoes. Those who are pregnant need to take extra precautions as there is greater risk to the unborn baby. All people need to work together to help protect pregnant people and unborn babies from the zika virus.

Q3. Knowing this, might you take action to avoid virus?

YES_____ NO_____

Please keep in mind that while zika is serious, reports of mosquitoes carrying zika in the Baltimore area have not been made. An infectious person would have to be exposed to a large population of mosquitoes that then survive long enough to bite a second person. This means that the risk is currently low, real-but not something people need to panic about. Certainly, pregnant women should take extra precautions to avoid mosquito bites. Zika is not spread casually from person to person (it can be sexually transmitted).

Q4. How does your taking care to avoid the virus help those who are pregnant?

PLEASE EXPLAIN: