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Science Communication Beliefs of Researchers Based in the Philippines and the United States: A Qualitative Analysis of Research Cultures and Worldviews

For the degree of Doctor of Philosophy

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SCIENCE COMMUNICATION BELIEFS OF RESEARCHERS BASED IN THE PHILIPPINES AND THE UNITED STATES: A QUALITATIVE ANALYSIS OF RESEARCH CULTURES AND WORLDVIEWS

A Dissertation

Submitted to the Faculty

of

Purdue University

by

Inez Ponce de Leon

In partial Fulfillment of the

Requirements for the Degree

of

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West Lafayette, Indiana

For Mama Emma.

We did it!

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ABSTRACT

Ponce de Leon, Inez. Ph.D., Purdue University, August 2011. Science Communication Beliefs of Researchers Based in the Philippines and the United States: A Qualitative Analysis of Research Cultures and Worldviews. Major Professors: Mark Tucker and B. Allen Talbert.

How do researchers' background cultures and worldviews influence their beliefs about science communication? To answer this question, 20 researchers from various research institutions in the Philippines and 20 researchers from Purdue University in West Lafayette, Indiana, USA were interviewed regarding their culture as scientists, surrounding culture, and views on various aspects of science communication. Interviews and researcher field notes were analyzed using a combination of frameworks: a combination of the definitions of culture, worldview, and science communication; and a combination of Swidler's culture-as-toolbox and Lam's boundary setting frameworks. Data analysis revealed that researchers in both cultural milieus differed in descriptions of their worldviews and science cultures. Filipino researchers tended to adopt a joint positivist/post-positivist worldview, where they wanted the public to believe in the stability of scientific facts, but admitted that scientific findings could change. U.S.-based researchers, on the other hand, adopted a post-positivist worldview, where they acknowledged their limitations as researchers and that knowledge changed. All researchers believed in

the dissemination model of science communication, where scientific knowledge is held in high regard, and where the lay public's duty is to listen to scientists. Subscription to the dissemination model was consistent with the worldviews that the researchers espoused. However, Filipino scientists wanted to communicate scientific facts, while U.S.-based researchers wanted to communicate the nature of scientific research, as well. The researchers also provided opinions on their surrounding culture: Filipino researchers tended to believe that habits unique to the Filipino culture, such as lack of assertiveness, were impeding science progress and exacerbating the poor funding situation, while U.S.-based scientists believed that American culture encouraged creativity and critical thinking and allowed them to deal with funding pressures. All researchers were willing to communicate directly with the public using tools provided by scientific training, but they were less willing to work with the media. While both groups of researchers wanted social scientists to adopt tools of the bench sciences to validate social science research, only the Filipino researchers tended to believe that social scientists could help increase the social acceptability of scientific work. Findings from this research can be used to help advance theoretical modeling in the context of science communication, particularly as it relates to the role of scientists in this process. Findings can also help improve science communication by understanding how scientists define themselves as key players in the communication process alongside other actors such as journalists, the public and other scientists.

CHAPTER 1: INTRODUCTION AND BACKGROUND

Introduction

There has been a growing interest in science, technology, engineering, and mathematics (STEM) in recent years. Governments acknowledge that science and technology contribute to economic growth and competiveness in the world market. As a result, many programs have been developed around the world in order to improve education in the STEM disciplines (Claessens, 2008; Committee on Science & U.S. House of Representatives, 1999). For instance, the National Science Foundation (NSF) of the United States supports several significant programs and initiatives that aim to improve education and student retention in STEM disciplines such as biology, geosciences, and environmental sciences, and even in the social and behavioral sciences (NSF, 2011).

A major goal of improved investment and education in the STEM disciplines is to encourage more young people to consider science as a career. However, not all students will be scientists, which necessitates that education extend beyond the classroom. One of the major ways that science education is carried out is through non-formal means of science communication. Science communication is the process of relaying scientific information to the lay public. Science communication can be carried out through informal and free-choice learning venues that include museums, fairs and science centers (Falk, 2001; Martin, 2001; Martin-Sempere, Garzon-Garcia,

& Rey-Rocha, 2008). Science communication is also carried out through mass media channels, such as television, radio, and print (Campbell, Martin, & Fabos, 2006). Today, science communication is also carried out through the Internet (Rodman, 2006).

The literature shows that various researchers define science communication in different ways as well. Field and Powell (2001) distinguished between the public understanding of science, which is static because it refers to how the public understands basic science; and the public understanding of research, which is dynamic and therefore more difficult for the mass media to cover. Burns, O'Connor, and Stocklmayer (2003) defined science communication as communicating both the meaning and implications of science activities, while the public understanding of science is defined as communicating scientific content, methods, and impact to the lay public in order to create awareness, enjoyment, interest, opinions, and understanding. Strauss, Shope, and Terebey (2005) defined science communication as "the explicit intercultural discourse that explains the significance of scientific research, the nature of science, the doing of science, and the content of science" (p.12).

Science communication benefits different sectors of society in different ways. Gregory and Miller (1998) outlined major benefits to the public understanding of science, which include tolerance for scientific work from the community at large; improved national economies; broader national power and influence; a more informed public; a more democratic government and society; and additional moral, intellectual, and aesthetic benefits.

The development of science communication is tied intimately with the history of modern science. Various books and review articles tackled this history in depth, and in a variety of ways. Researchers have formulated models of scientific development in terms of breakthroughs over the centuries (Kuhn, 1970), traced how theoreticians have interpreted the actions of scientists (Chalmers, 1999), tracked the strengthening ties between science and industry, and chronicled the development of various science communication practices (Logan, 2001; Schiele, 2008).

There are several noteworthy points in the literature. For one, science communication is a craft that is as old as the Age of Enlightenment. Scientists sought to dispel the popularity of alchemy and the occult by using science as an instrument of rationality (Schiele, 2008). To do so, they reached out to the people and carried out their own communication. For instance, Michael Faraday held Christmas lectures 19 times between the years of 1827-1860 on various scientific topics, and opened these lectures up to the general public (Gregory & Miller, 1998). Slossen, Heyl, Millikan, and Hale carried out science communication in the early 20th century in order to encourage young students to pursue science, increase public interest in science, and increase public support for science (Logan, 2001).

As the 20th century progressed, however, science became increasingly complex. There were more scientists carrying out more research, and research progressed swiftly in various fields under the pressures of various political and economic changes, such as World Wars I and II, and the Cold War (Schiele, 2008).

The mass media also became more popular, and growing technology brought information to a greater number of people, and at a faster rate.

It was not enough for scientists to simply reach out to the public on their own, especially when their science was far too complex to be explained in simple, everyday terms, in the way that Faraday and his colleagues could, and did (Schiele, 2008). The mass media thus took on the role of mediators: they simplified scientific information in order to make it more palatable for public consumption.

Today, the mass media is still tasked with mediating between researchers and the lay public. The mass media repackages information from scientists, and then communicates information through various channels, such as radio, print, television, and in recent years, the Internet. Science information is also presented in various genres, such as feature shows, documentaries, news, books, magazines, blogs, websites, and the like. Although the mass media are not involved in museums and science centers, such places are still popular avenues for showcasing research.

Even with mediation by the mass media, however, scientists are still called upon to communicate their findings to the lay public. They are the ultimate source for science-related stories, are most intimately connected to their research, and are the most credible sources for scientific information. This need for scientists to communicate science has been made all the more pressing by science-related issues in the press, such as the Cold War, Sputnik, Rachel Carson's "Silent Spring," various environmental disasters around the world, the Chernobyl disaster, bovine spongiform encephalopathy (BSE) or "Mad Cow" disease, and comet or asteroid collision scares (Erickson, 2005; Gregory & Miller, 1998). A quarter of the top news stories in *Discover Magazine* for 2010 involved human health issues, another quarter revolved around astronomy and physics, and yet another quarter showed how bench science tools were aiding sociology and psychology (Discover Magazine, 2010). On the other hand, *Scientific American* (2010) included various natural disasters, microbes, and advances in sustainability as part of its top stories for 2010.

Various governments have also promoted science communication by scientists themselves. For instance, in the United States, the Committee on Science and the U.S. House of Representatives (1999) released a report that called for scientists to recognize that they had a responsibility to communicate their findings to the public, as well as to make science more salient. The report, *Unlocking our Future: Toward a New National Science Policy*, called for bridges to be built between scientists and journalists, and for scientists to report the findings of publicly-funded research. There are also professional organizations and media groups that promote the public understanding of science, and with the help of researchers. For instance, the Discovery Channel and the National Geographic Society in the United States broadcast television shows that allow myths and urban legends to be confirmed (or disconfirmed) by scientific experiments, provide a way for people to explore the natural world from the comfort of their living rooms, and give viewers information on how certain modern machines work. *Scientific American* and the *New York Times* are also popular venues through which scientific information is disseminated in the United States. In the United Kingdom, the Royal Institution Christmas lectures made famous by Faraday in the 1800s still take place every year (The Royal Institution of Great Britain, 2008). The lectures have since tackled topics such as food processing, mathematical mysteries, and climate change; these lectures are broadcast on television, and several videos are available in online archives (The Royal Institution of Great Britain, 2008). Both the Discovery Channel and the National Geographic Society Channel are broadcast in the Philippines, but the Philippines also has its own Knowledge Channel, which broadcasts local shows hosted by academic scientists. These scientists give television lectures on basic biology, chemistry, and physics (The Knowledge Channel, 2009). In many countries all over the world, scientists participate in science festivals, and are also called upon by the media to deliver statements on different issues, such as flu outbreaks, climate change, and genetically modified organisms.

Risk communication is another field that has become more important in recent years, and especially due to many science-related issues in the press. Often associated with communication in times of crisis and disasters, risk communication presents its own challenges. Risk communication is defined as the communication of risk information in order for an audience to understand risks and provide them the means to act appropriately when such a risk arises (Department of Homeland Security, 2008). Various scholars, such as Sandman (2003), have also differentiated amongst the various types of risk communication according to their corresponding hazard and outrage levels in the lay public. Risk communication is also another avenue through which researchers can communicate to the lay public, and another communication field where scientific research is needed in order to inform the content of a message.

Clark and Illman (2001) referred to communicating researchers as civic scientists, in that such scientists reach out to the public in order to increase appreciation for, support for, and knowledge of science. Research has also shown the benefits that scientists gain from communicating about their work. Burns et al. (2003) said that scientists develop their communication skills, clarify their understanding, and gain fresh perspectives on various issues related to their research. Riise (2008) believed that scientists should communicate in order to gain public trust and sympathy. Studies on scientists, in general, have found that they communicate because communication activities can help them secure funding (Gascoigne, 2008), or they simply enjoyed it (The Wellcome Trust, 2001) even if their peers did not approve and the activity took time away from their research (The Royal Society, 2006). The motivation for civic scientists to communicate, Greenwood and Riordan (2001) claimed, "comes from a different place in one's being – the citizen rather than the scientist" (p. 38).

As scientists provide sound scientific information, mass media can repackage it, and then relay it to the lay public. This information should help the lay public understand science, as well as be informed on what to do or believe when they are confronted with science-related issues in the press. With a more scientifically literate society, support for science and economic growth should therefore ensue.

Such an aim, however, is not only far from being realized, but difficult to attain. First, modern science has expanded far beyond the borders of the physical and natural sciences, and has influenced the growth of other fields, such as psychology, anthropology, and economic theory. Science, moreover, is a field that is as difficult to understand as it is to teach. Not only is modern science more complex, but its foundations are entrenched in jargon and ideas that are difficult to grasp without years of science training.

The potential for science communication has not yet been realized, and this may be due to various factors. For one, the relationship between scientists and journalists is far from peaceful. Some researchers believe that the media lacks objectivity (Gunter, Kinderlerer, & Beyleveld, 1997), responds too much to popular interests (Claessens, 2008), and can be too hasty with reporting what scientists deem to be tentative findings in their research (Van den Brul, 1995). Not all scientists are opposed to media coverage of science (Neilsen, Kjaer, & Dahlgard, 2007; Peters, Heinrichs, Jung, Kallfass, & Petersen, 2008) but they are often reluctant to do so because of the risk of being misinterpreted.

Nevertheless, science is finding itself thrust further and further into the public sphere, not only because of increased science coverage in the press and a greater emphasis on science education, but because many high-profile events are also science-related. Recently, the British Petroleum p.l.c. (BP) oil spill in the Gulf of Mexico required scientists and engineers to speak up about how the oil spill should be cleaned, how it could be avoided in other places, and damages that could accrue to local flora and fauna. The spread of scientific information and the visibility of scientific work have also been aided by television and the Internet. At the same time, when scientific information is released through such channels, it cannot be controlled; in the same manner, misinformation can spread fast and be difficult to stop when it spreads through electronic channels.

The public is also more critical of scientific work and scientists, and recent studies have shown that the public does not completely trust science. A recent poll by *Scientific American* (2010) showed that the public tends to trust scientists on specific topics (for instance, evolution, renewable energy, and the origin of the universe) but not on others (for instance, genetically modified crops, pesticides, depression drugs, and flu pandemics). The poll also showed how trust varied among different countries. People in Germany approved of scientists being involved in politics, but people in China did not (Scientific American, 2010). Most people also believed that science funding should not be cut, and recognized that science was a long-term investment that did not always have immediate applications (Scientific American, 2010). Nevertheless, the public still expressed fears over technology such as nuclear power, and, to some extent, nanotechnology and genetically modified crops (Scientific American, 2010).

A possible reason for the lack of growth and success of science communication can also be attributed to the fact that the task of communicating to the lay public is not widely popular among scientists. The task of popularizing science is often perceived as an oversimplification of complex scientific facts, the scientific profession, and the process of arriving at valid scientific knowledge (Gregory & Miller, 1998; Pels, 2003; Weigold, 2001). Advocating for science, some scientists believe, contradicts the disinterest that the scientific field claims to possess; this lack of objectivity might translate to compromised work integrity (Gascoigne, 2008). Some researchers saw it as a clash of values, between those of the scientific community and those that researchers hold personally (Van den Brul, 1995). Researchers have also called for a better definition of what exactly is expected of them in terms of public engagement and communication (The Royal Society, 2006) and a definition of the roles that scientists and journalists need to play (Treise & Weigold, 2002).

Moreover, for some researchers, the task of communication is usually done by scientists who do not do the “real” work of science (Jensen, Rouquier, Kreimer, & Croissant, 2008, p. 528). This notion is often referred to as the Sagan effect, in reference to Carl Sagan, the well-known astronomer who was a prominent media figure; but who, despite the effect that bears his name, was quite productive in research and well-published in major science journals (Jensen et al., 2008).

The new relationships among scientists, industry, and university can also prevent scientists from carrying out science communication. Universities mandate that their researchers carry out public outreach and communication, but also demand that researchers continue their research work. It is only through research work that scientists are awarded. This clash of priorities has often been referred to as a transition from Mode 1 to Mode 2 research: in Mode 1 research, research is enclosed within the university and specialization is encouraged, but in Mode 2 research, various fields are interdependent and research has to be put in its social context. That is, research must be needs- and demand-based (Cohen, McAuley, & Duberley, 2001). Research is rewarded in Mode 1, but communication and outreach should be rewarded in Mode 2. However, many universities advocate the move to Mode 2, but still practice the reward systems of Mode 1 (Jacobson, Butterill, & Goering, 2001).

This increasing call for scientists to communicate is occurring alongside the changing face of the research culture. This change has been studied in the United States, where Varma (2000) interviewed scientists and managers, and found that research is increasingly driven by commercialization and applications. There is a thinner line between basic and applied research as the university and industry collaborate in order to produce research (Lam, 2010). According to Lam (2010), industry work has made scientists draw and define boundaries between themselves and industry. Lam's (2010) classification scheme groups scientists into Tight Boundaries, or those who refuse to work with industry; Traditional Hybrids, or those who are willing to do some industry work, but who feel role identity tension between science and industry; Entrepreneurial Hybrids, or those who are willing to do some industry work, but feel no role identity tension; and Entrepreneurial Scientists, or those who are completely open to working with industry but find it difficult to reconcile academic and industry work. While industry involvement can spur research forward, legal constraints, such as copyrights, patents, and confidentiality agreements can keep scientists from sharing and publishing their work (Anderson, Ronning, De Vries, & Martinson, 2007; Cohen et al., 2001; Jacobson et al., 2001; Lam, 2010; Varma, 2000).

The lack of success in science communication might actually be due to the field itself. As a field, science communication is generally tasked with examining the process of relaying scientific information to the lay public. Science communication is composed of various professionals coming from the bench sciences, journalism, communication, sociology, anthropology, psychology, computer science, and the visual arts. The concept of science communication is often used interchangeably (and even confused) with concepts such as science education, the public understanding of science, public communication of science and technology, public engagement, or the public understanding of research. It can also be defined according to the stakeholders who are carrying it out, whether they are from the academe, industry, or government. Science communication, therefore, can also be defined in many different ways, depending on the needs and goals of the stakeholders involved. In the words of Durant (1999), the public understanding of science is an “uneasy coalition of many different professional and social interests” (p. 314).

This uneasy coalition has led to a field that has many goals and possible definitions, but it has also resulted in a field that has no paradigm or central tenets around which research and practice can be built. Perhaps as a result of this lack of an overarching paradigm, much research in science communication has been descriptive. There are reports on what kinds of scientific breakthroughs are covered in the media, what kinds of mass media encourage science learning outside the classroom, or what professional science communicators believe make a compelling science story. In terms of the scientists themselves, research has been undertaken, in general, on what scientists think about the task of communication (Davies, 2008), why they are turned off by having to communicate (Peters, Brossard, et al., 2008), and what they think about the mass media and the lay public (Claessens, 2008; The Royal Society, 2006; The Wellcome Trust, 2001).

The phenomenon of Clark and Illman's (2001) civic scientist has also been studied in the literature, and through different investigative methods. Research has been focused so far on large surveys of scientists or interview data, and has asked scientists about their motivations to communicate and the communication activities that they undertaken so far. However, there may be other factors that can contribute to and affect a researcher's decision to communicate with the lay public. Such factors can include the researchers' work environment, the researchers' personal worldviews, and the culture of science itself.

A worldview encompasses how people view the nature of the world, their place in it, and the relationship of the world to its parts (Guba & Lincoln, 1994). A personal worldview includes a person's ontology, or views on the nature of reality; epistemology, or views on the nature of knowledge; methodology, or valid ways to obtain that knowledge; and a perception of how the world is related to its parts. For instance, the positivist worldview conceives of science as a search for truth, where scientists can be objective and can work independently from society, so that their work will not be influenced by anything else except the scientist's own need to find the truth (Guba & Lincoln, 1994). In positivism, objectivity resides in the individual scientist. In such a worldview, knowledge can be used to know reality, predict nature, and control it. The world is seen as a system of cause-effect patterns that scientists can measure and describe with careful methodology. Within this worldview, experiments and measurable quantities are held in high regard.

Post-positivism is the response to positivist ideals. In such a worldview, accurate measurements are not always possible due to limits in technology, the background of the scientist, the theories being used for research, and general human error. Post-positivism holds that individual scientists are incapable of complete objectivity, but objectivity can still be achieved if methodologies are repeated by different researchers in order to confirm and triangulate findings (Guba & Lincoln, 1994). In other words, post-positivism asserts that objectivity is a social phenomenon, and not resident in individual scientists. Post-positivism also holds that science can only approximate reality. Moreover, post-positivism does not draw distinctions between scientific methods and everyday thinking. Positivism and post-positivism share a common ontology: in both worldviews, reality is independent of humans, and can be measured, although in varying degrees of accuracy (Guba & Lincoln, 1994).

The concept of worldviews can be important in studying scientists. A worldview can affect what scientists consider valid knowledge and methodology (Eigenbrode et al., 2007) and what students of science believe to be their job as future scientists (Buffler, Lubben, & Ibrahim, 2009).

The cultures of researchers can also be important in determining what research scientists can do, and what scientists value as a group. These cultures can come in two major forms: the national cultures that surround the scientists, and the culture that scientists hold amongst themselves. These cultures can be described by examining the cultures' norms, values, rewards systems, punishments, and sanctions. The culture that the researchers are socialized into can also provide them with tools to deal with the changing culture of science (Swidler, 1986), where they are expected to deal with industry, the mass media, and the lay public, all in addition to fulfilling their research obligations. The research culture can likewise be described by examining the lines that researchers draw between themselves and industry, the mass media, and the lay public: such lines can provide information on what the researchers perceive to be their obligations and responsibilities (Lam, 2010). A definition of these boundaries can also valuable in science communication, which is a consolidation of many different disciplines.

Studying the worldviews and cultures of scientists, therefore, can be valuable for science communication. The worldviews and cultures of scientists can dictate and affect what activities they choose to do, and in order of what importance. The worldviews and cultures of scientists can also dictate what they believe the goals of science communication should be, what aspects of science should be communicated, and what the lay public should know about science and research. The worldviews and cultures of scientists can also provide insight into what the researchers believe their responsibilities are in science communication, and what tools they are using to deal with the demands of the modern science culture.

Scientists may also be affected by their national cultures, especially where funding priorities and government policies are discussed. For instance, in the Philippines, research funding is directed primarily to groups that belong to top universities, promise marketable products or services in the short term, and have a social sciences/social acceptability component attached to their work (Department of Science and Technology, 2011). The Philippines has also been colonized several times, first by the Spanish, then the Americans, then the Japanese (Caoili, 1986).

Science communication also became a much larger issue when the Philippines became the first country in Asia to adopt Bt corn, which led to protests from various farmers and non-government organizations, and counter protests from scientists and government (Navarro, Escaler, Ponce de Leon, & Tababa, 2007). Current demands on scientific work and issues in the lay public can affect what researchers choose to do research in. Past history and the surrounding national culture can affect how researchers behave and what they might feel is appropriate scientific behavior.

Scientists have their own worldviews, national culture, and science culture that they bring to the table. Such worldviews and cultures cannot be changed, and their existence cannot be denied. The worldviews and cultures of scientists can affect how they think, behave, and reason on a variety of issues, including the practice of science and science communication itself. As the ultimate source of scientific information, scientists also take these worldviews and culture with them, and these worldviews and cultures must be understood in depth if scientists are expected to communicate and work with a variety of professionals and the lay public. A deeper understanding of the worldviews and cultures of scientists, moreover, can contribute to a theoretical base in the field of science communication.

Significance of the Study

Current and past research in science communication has often been concerned with describing various aspects of it, such as what issues receive the most coverage, what constitutes entertaining science-related messages, and how various stakeholders have reacted to different issues in the press. These are largely "counting exercises" which have value in informing science communication practice, and perhaps in predicting what science issues will receive the most attention from the lay public. However, more studies are needed in order to establish a firmer theoretical base for science communication.

The growth of a theoretical base in science communication can be initiated through theoretical and conceptual frameworks, which can be used to examine various aspects of science communication: some frameworks can be used to analyze or classify the process of communication, others can be used to examine the motivations of researchers for communicating, and still others can be used to examine these motivations against a backdrop of culture, environment, and worldviews. Because theoretical and conceptual frameworks focus on specific aspects of science communication, these frameworks can also guide future research: they can determine what issues still need to be addressed in future studies, and what questions need to be asked in order to address these issues in depth.

Moreover, scientific disciplines require a strong, firm theoretical foundation on which to base empirical studies (Trench & Bucchi, 2010). Previous research in science communication has been on how science-related messages can be made more entertaining or efficient. According to science communication scholars such as Trench and Bucchi (2010) and, to some extent, Weigold (2001), such a research strategy has stunted the growth of the field. Research has to be carried out in order to define who is communicating what when it comes to science communication, why science communication is the way it is, and how it is structured (Trench & Bucchi, 2010).

There are also very few studies that carry out cross-cultural analysis. Despite the claim of scientific objectivity and science as an overarching culture, scientists all over the world might be different from each other. Their personalities, cultures, and goals can change the pace of a research project, determine what will be done with the findings, and even determine who will be the mouthpiece for science when all is said and done.

This research will use various theoretical and conceptual frameworks drawn from the literature on science communication, the nature of scientific practice, and culture to explore the lives of researchers who work in the Philippines and the United States.

The findings of this research can be used to develop training programs that will help future researchers in their science communication efforts. Such training programs can be important as universities continue to build the capacities of their staff, create reward systems for communicating science, and engage in issues management. As researchers are increasingly held accountable for their research, they should be provided with science communication training that will help them deal confidently with the mass media, lay public, and other audiences of science communication.

The findings of this research can also be used by journalists, the mass media, and other stakeholders and participants in the process of science communication. A deeper understanding of the science culture and the worldviews of scientists can lead to better collaboration amongst those involved in communicating science to the lay public. Moreover, a deeper understanding of the science culture and the worldviews of scientists can lead to better collaboration amongst those involved in trans-disciplinary collaborative research, where various worldviews and cultures often meet and clash.

The findings of this research can be used as a stepping stone to understand the phenomenon of the civic researcher, as well as to direct future research that will allow for an even deeper understanding of researchers who engage in science communication. The use of theoretical and conceptual frameworks in this study can also be adopted by other science communication researchers as they design their own methods for investigating science communication.

Finally, the findings of this research can contribute to the growth of theory in science communication research and practice. The use of theory in science communication can focus science communication studies, and provide practitioners with theoretically-driven tools. It is only when science communication is practiced well that it can benefit all those who take part: scientists, engineers, science communicators, policymakers, and the lay public.

Purpose of the Study

This research will use various theoretical and conceptual frameworks drawn from the literature on science communication, the nature of scientific practice, and culture to explore the lives of researchers who work in the Philippines and the United States. This research will also generate themes from the data that will allow the participants to define their practice, culture, and science communication in their own words. Twenty (20) science and engineering bench researchers from the Philippines, as well as 20 science and engineering bench researchers from Purdue University in the United States, will be interviewed. Their interviews and accompanying field notes will be analyzed deductively, with elements of induction. Each group of researchers from each country will be studied in-depth within their own cultural contexts.

Research Questions for the Study

This study aims to answer the following questions for each cultural context:

1. How do the participating researchers define science and risk communication?
    - What is their definition of science communication and risk communication?
    - What do they think the goals of science communication and risk communication should be?
    - What do they believe their role is in communicating science to the lay public?
2. What are the worldviews and cultures of the participating researchers?
    - What is the worldview of the participating researchers?
    - What is the culture of the researchers?
    - How does the surrounding culture of the researchers affect their work?
3. What does it mean to be a civic researcher?
    - What science communication model do the researchers follow?
    - What is the culture of the civic researchers?

- What boundaries do the scientists set between themselves and the lay public? Themselves and communicators?

4. What additional concepts, though not covered by the conceptual frameworks, are important from the standpoint of participating researchers?

In order to answer the research questions, this study will carry out deductive analysis, with elements of induction. Deductive analysis of the data will be conducted using the following combinations of theoretical and conceptual frameworks drawn from the literature:

1. The combined frameworks of worldviews by Guba and Lincoln (1994) and science communication programs by Trench (2008). When used together, these two frameworks link researchers' views of reality, knowledge, and scientific methods with their opinions on the goals of science communication.

2. The combined frameworks of settled and unsettled lives by Swidler (1986) and an adapted Lam (2010) framework of science-industry boundary negotiations. When used together, these two frameworks examine civic science as a culture in flux. According to these perspectives, the researchers' commitment to communication varies depending on (a) the tools that the science culture possesses to deal with the task of science communication and (b) the researchers' perception of the strength of boundaries between research and other social institutions. These boundary negotiations will be explored in the forms of (a) science versus communicators and (b) science versus the lay public.

Inductive analysis of the data will also be undertaken in order to examine how the participating researchers define science communication. Inductive analysis will also be used to generate themes from portions of the data that are not explicitly addressed by the theoretical and conceptual frameworks that will be used, but that may nevertheless have bearing on future research regarding science communication.

Limitations of the Study

This research has several limitations. First, the theoretical and conceptual frameworks that are used in this research are based on previous literature. There may be aspects and facets of worldviews, culture, and science communication that have not yet been addressed in the literature, and are therefore not yet explored in this research.

Second, the participants in this study are taken from the bench sciences and engineering. Researchers in the bench science and engineering will be different from researchers who work in the social sciences. The two groups of researchers are different: they work with different methods and are concerned with different kinds of data. Therefore, the findings of this study, and the opinions of its participants, cannot be extended to social scientists.

This research operates through a post-positivist stance. That is, only an approximation of reality may be reached, and data is triangulated through different sources in order to achieve objectivity. These sources include field notes before and after interviews, and interviews of participants. There are internal controls installed in the code book for analyzing data to ensure that interviewed data is always labeled and coded the same way no matter which framework is being used.

Researchers who are involved in quantitatively-based research might perceive that working with qualitative data is problematic because it cannot be generalized to a larger population. However, this concept of generalization is unique to the quantitative research paradigm, which uses statistics to validate and analyze research findings (Merriam, 1995). This concept of generalization does not apply to qualitatively-based research. Instead, this study relies on the concept of concrete universals, which are ideas and concepts that transcend the event or phenomenon from which they originate. However, because the interview tool asks about the cultures of scientists, the outside forces that influence how science is carried out, and the scientists' perception of their native cultures, the interview tool may still be used by other researchers to investigate other scientists in other cultures.

Validity and reliability must also be conceived in terms of the qualitative research paradigm. Internal validity measures the accuracy of the instrument of the research, the researcher herself. Reliability is measured through whether the results are consistent with the data collected. External validity, as mentioned above, relies on concrete universals. This research aims to "understand the particular in depth, rather than find out what is generally true of many" (Merriam, 1995, p. 57). All these were ensured through triangulation of data (using more than one data location and more than one data source), and will continue to be ensured using a statement of research orientation, an audit trail, and thick descriptions. Triangulation was also carried out by embedding duplicate typologies within the codebook to ensure that the researcher was coding the same statements in the same ways.

Definition of Terms

This research employs terminology for which definitions vary in the literature. This subsection of the Introduction specifies the definitions used by the researcher in carrying out this research.

- Bench science: a collective term that is used in this research to refer to the fields of study that fall under engineering, the natural sciences, the physical sciences, and mathematics. The participants in this study are from the bench science or engineering, or work in both fields. For purposes of narrowing the field of study, social scientists were not included in the participant pool.
- Culture: a term that is used in this research to refer to the norms, values, and sanctions shared by a group of individuals. This culture may be shared at the national level (Filipino or American) or at the professional level (Researcher, scientist, or engineer). This is a consolidation of definitions set forth in the literature by Berk, Korenman, and Wenger (2000); Chalmers (1999); Erickson (2005); Gregory and Miller (1998); and Guba and Lincoln (1994).
- Field notes: a term that is used in this research to refer to notes taken before and after the interview with the participants. Field notes are taken to disclose researcher biases, as well as to describe the participants' workplace, demeanor, and post-interview discourse.
- Filipino: For this research, the term "Filipino" will be used to denote researchers who are based in the Philippines, regardless of their country of origin. This group of researchers will be limited to scientists and engineers

who have doctoral degrees in the bench sciences and engineering, and who are currently teaching or have teaching experience.

- Interview: a term that is used in this research to refer to the process of asking participants questions from a predetermined, field-tested instrument. Interviews were conducted with an audio recorder and full consent of the participants. Participants were allowed to refuse answer interview questions, terminate the interview, ask for clarifications, and go off the record with their answers.
- Mass Media: in this research, mass media will refer to print and electronic channels of communication that are used to disseminate news and science-based information to the lay public (Campbell et al., 2006; Rodman, 2006)
- Norms: a term that used in this research to refer to the customary behavior of researchers and how they are expected to behave in science. This is a consolidation of definitions set forth in the literature Berk et al. (2000); Chalmers (1999); by Durlauf and Blume (2011); Erickson (2005); Gregory and Miller (1998); and Guba and Lincoln (1994).
- Off the Record: a term that is used in this research to refer to keeping answers confidential on the prompting of a participant. In going off the record, a participant is still allowed to discuss an issue and provide opinions, but with the audio recorder shut off. Recording resumes only when the participant provides verbal consent for the interviewer to do so.
- Sanctions: a term that is used in this research to cover the taboos and corresponding punishments of poor researcher behavior. This is a

consolidation of definitions set forth in the literature by Berk et al. (2000); Chalmers (1999); Erickson (2005); Gregory and Miller (1998); and Guba and Lincoln (1994).

- Science communication: a term that refers to the practice of relaying scientific information to the lay public, as well as the field of study that deals with investigating this practice. The relaying medium may be the mass print and broadcast media, electronic media, museums or science centers, or directly to the lay public through events such as lectures, science fairs, or science festivals. This scientific information can refer to bench science and engineering knowledge, research methods in both bench science and engineering, and the implications of bench science and engineering findings. This definition of science communication is a consolidation of definitions provided by the literature, and set forth by Burns et al. (2003); Gregory and Miller (1998); Logan (2001); and Trench (2008).
- Values: a term that is used in this research to refer to the character traits, behavior, and concepts that participants hold in high regard. This is a consolidation of definitions set forth in the literature by Berk et al. (2000); Chalmers (1999); Erickson (2005); Gregory and Miller (1998); and Guba and Lincoln (1994).
- Worldview: a term that is used in this research to refer to a person's ontology (view of reality), epistemology (view of knowledge), valid methodology (view of obtaining knowledge), and conception of the relationship of the world to its parts (Guba & Lincoln, 1994).

Basic Assumptions

This research assumes that scientists and engineers are bound by their own culture as professionals. This culture will have its own systems of norms, values, and sanctions. The participants are also assumed to have their own personal worldviews, which comprise the participants' ontology, epistemology, methodology, and a perception of the relationship between the world and its parts. This research assumes that scientists and engineers will be influenced by these worldviews and their professional culture, and by the national culture with which they are surrounded as well.

This research assumes that the participants can articulate the components of their culture as researchers, their culture as members of a larger culture, and their worldviews. It is assumed that the participants will be able to articulate these components through interviews, and that their articulations are truthful as far as the participants can perceive it. It is also assumed that the participants' opinions will be manifest through interviews, and that each opinion is both truthful and valid.

This research also assumes that the participants know of the demands for scientists to communicate their research to the lay public. This research assumes that the participants can articulate what they perceive to be the tools provided by science to cope with the demand, as well as what they believe to be their role in science communication. This research assumes that with prompting, participants can talk about their opinions of and experiences in working with the mass media.

This research assumes that the conceptual and theoretical frameworks can provide an approximation of the cultures and worldviews of the participants, the perceived tools that culture can offer to deal with the demands of modern science, and the perceived boundaries that researchers set between themselves and various participants in science communication. When these frameworks are used to examine the interviews and field notes, it is assumed that they will answer the research questions.

CHAPTER 2: LITERATURE REVIEW

The literature review was conducted by searching for research articles and books through the Purdue University libraries' database. The following search strings were used: "science communication", "worldviews of scientists", "nature of science and scientists", and "sociology of science". Articles and books were gathered in order to achieve a broader view of the landscape of current science communication research. In addition to these articles and books that were found through the database search, there were also articles and books that the researcher used in her coursework that were also helpful in forming the dissertation research questions. To update the literature review, the researcher took note of the journals that provided the greatest number of research articles related to her topic. These were *Science Communication*, *Journal of Science Communication*, *Public Understanding of Science*, *Social Studies of Science*, *International Journal of Science Education*, and *Science Education*. The websites of these journals were checked each month, beginning in March 2009, for updated articles that could be used to further inform the literature review.

The literature review is divided into 4 major sections. The first section, "Major Developments in Science Communication", chronicles the development of science communication alongside modern, Western science. The second section, "Science, Communication, and Society", summarizes research in science communication by featuring different studies that have examined various aspects of scientific practice as they relate to civic science. The third section, "Models of Science Communication", provides summaries of the models that researchers have used to organize science communication research and practice. The last section, "The Cultural Contexts", provides a brief history and background of the Philippines and Purdue University, the cultural contexts of the participants in this study.

Major Developments in Science Communication

Science communication has become a necessity, with the advent of modern science. Various books and review articles examine how science communication and modern science have developed together. For instance, Kuhn (1970) provides a model for changes in scientific paradigms, aided in part by published research that allows science to move forward via scientific breakthroughs. Chalmers (1999) has consolidated the views of various theoreticians and philosophers of science, and has shown the various interpretations of how scientists reason, from falsification to the adoption of Lakatosian research programs. In addition, researchers in the social studies of science (for instance, Logan, 2001 and Schiele, 2008) have chronicled the development of science communication practices and methods.

The art and craft of science communication dates back to the Age of Enlightenment, when scientists fought the popularity of the occult and alchemy using the rationality of science (Schiele, 2008). Scientists such as Faraday, Slossen, Heyl, Millikan, and Hale communicated directly with the public (Gregory & Miller, 1998; Logan, 2001). However, the complexity of science and the rise of the mass media in the 20th century provided the environment for two things to occur: scientists could no longer communicate directly to the public because science was too complex for the public to understand (Schiele, 2008), and the mass media became mediators between the lay public and researchers.

The mass media still carries out that mediation today, but the channels have expanded. Science communication can be carried out through television, cinema, books, magazines, news, museums, science centers, and various Internet-based media. What remains constant, however, is the need for scientists to communicate their findings to the lay public, whether directly or as consultants, and even as the relationship between journalists and scientists is unstable (Davies, 2008; Peters, et al., 2008). This need to communicate is made urgent by science-related news in the press, such as the Cold War, Rachel Carson's "Silent Spring," (Erickson, 2005; Gregory & Miller, 2008) and recently, the BP oil spill in the Gulf of Mexico.

This need to communicate research is also promoted by governments. In the United States, the report *Unlocking our Future: Toward a New National Science Policy* (Committee on Science & U.S. House of Representatives, 1999) called for more scientists to communicate their findings and make them salient to the lay public. Professional organizations and media groups also promote the public understanding through the help of researchers. Such outlets for communication include the Discovery Channel, the National Geographic Society, *Scientific American*, and the *New York Times* in the United States; the Christmas Lectures in the United Kingdom; and the Knowledge Channel in the Philippines.

Several new fields of communication have developed with the increase of science-related issues in the press. Risk communication, for instance, deals with communicating risk information to an audience in order for the audience to understand the risk and deal with it appropriately (Department of Homeland Security, 2008). Various scholars have since conducted research on risk communication and its various components (Sandman, 2003). Risk communication also needs scientific research to support the various claims that it makes. Scientists also participate in risk communication activities, whether at the forefront or as consultants to the media.

Researchers who communicate to the lay public to increase appreciation for, support for, and knowledge of science have been called civic scientists (Clark & Illman, 2001). Research has shown the benefits that scientists gain from carrying out such work: they develop their communication skills, clarify their understanding of their work, gain fresh perspectives of various issues related to their research, and gain public trust and sympathy (Burns et al., 2003; Riise, 2008).

Science communication, however, can be difficult, and on many different grounds. First, science is difficult subject to understand, much less communicate. Second, many researchers do not trust the media and do not like working with the mass media (Claessens, 2008; Gunter et al., 1997; Van den Brul, 1995). Third, polls have shown that the public does not trust the opinions of scientists on all science-related issues (Scientific American, 2010). Fourth, the task of communicating research is not popular amongst researchers (Gascoigne, 2008; Gregory & Miller, 1998; Pels, 2003; Weigold, 2001). Fifth, researchers might be constrained by industry links that legally bind them not to publish or talk publicly about their research work (Cohen et al., 2001; Jacobson et al., 2001; Lam, 2010; Varma, 2000).

Moreover, science communication might not have developed and realized its full potential due to the diversity of views that inform the field of science communication itself. Science communication is defined in many different ways depending on the stakeholders and participants involved in the process. As a field, science communication lacks an overarching paradigm around which research and practice can be built. There have been calls, however, for both the use and construction of theory in order to inform science communication research (Erickson, 2005; Trench & Bucchi, 2010; Weigold, 2001).

Science, Communication, and Society

There is an area of scholarship focused on the place of scientists in society, their role of science communication, and role of research. There is literature available on the characteristics and culture of scientists, but the call continues for more work into scientific worldviews (Erickson, 2005) as well as the impact of the surrounding culture on the way that science is conducted (Spiegel-Rosing, 1997). In order to understand the worldview of scientists, researchers will need to "deconstruct the categories that scientists use to describe themselves (Erickson, 2005, p. 146).

It can be difficult, however, for scientists to articulate their answers to abstract questions such as, "What is your worldview?" The term "worldview" has many different definitions, depending on the field in which it is used. As a result, researchers have asked scientists what their values and norms are, what their responsibilities are as scientists, what methods they use to make decisions in their jobs, and what data is seen as scientific. When the worldview is broken down into specific components, it may be easier to understand, operationalize, and therefore measure.

Research has been conducted on the ontology and epistemology of researchers, or their view of reality and the nature of knowledge, respectively. For instance, Yore, Hand, and Florence (2004) used semi-structured interviews and questionnaires to ask scientists from a Canadian university about their views on science and science writing. The researchers found that the participants espoused a naïve realist ontology: they believed in an objective reality that cannot be accurately measured, but which scientists were slowly beginning to understand (Yore et al., 2004). The researchers also believed that knowledge changes and current understandings are limited by technology (Yore et al., 2004).

Research has been conducted on the views of scientists regarding scientific inquiry and knowledge. In a study of female scientists, Monhardt, Tillotson, and Veronesi (1999) found that female researchers at a large Midwestern university considered both objectivity and intuition as valuable traits in science, and added that scientists need to be persistent but caring. They also talked about the importance of mentors, their educational background, and various barriers to pursuing their scientific careers. The scientists believed that scientific knowledge is cumulative, truth is tentative, and some cultures could keep people from pursuing science. The same views were found in Schwartz's and Lederman's (2008) study of experienced scientists, who added that creativity is important to scientific inquiry; Yore, Florence, Pearson, and Weaver, (2006), who documented the views of two scientists on the nature of their practice; and Wong and Hodson (2009), who compared the views of scientists from different countries. While the views on creativity were echoed in the participants of a study by Burchell (2007), the scientists in the study believed in a strict scientific method.

Research has also been conducted on the personality traits that scientists value in other scientists, and such findings can provide information on the moral order of scientists as a group. In a study by Hermanowicz (2006), 60 physicists from the U.S. said that scientists needed to be persistent, smart, civil, aggressive, creative, and entrepreneurial. Success was defined as good performance in research, which included publishing the results of one's research work. In a study of norms and ethics, Berk et al. (2000) found that scientists were more concerned with issues in scientific cooperation, while administrative officials in a university were more concerned by issues surrounding conflict of interest.

Various studies have also been conducted on the personal beliefs of scientists. For instance, Falcão (2008) examined the religious beliefs of scientists from the United Kingdom and Brazil, and found that Brazilian scientists retained a belief in God while their counterparts in the United Kingdom did not. Coll and Taylor (2004) studied the superstitious beliefs of scientists, and found that the scientists were willing to believe in aliens, ghosts, and other supernatural phenomena if these phenomena were tested by controlled experiments, or if they were supported by simpler alternative explanations. A similar study by Coll, Taylor, and Lay (2009) found that scientists believed in a higher power due to their personal experiences, a simple personal belief, testimonies by their peers or friends, belief that science could one day explain religious beliefs, and awareness that they still did not know enough about the world.

On the other hand, a separation of personal belief from professional belief was evident in a survey of over a thousand Indian scientists by Keysar and Kosmin (2008). Their study revealed that while scientists were devoted to Hinduism, they were still tolerant of beliefs such as evolution, and supported animal research, both of which run contrary to the researchers' religious beliefs (Keysar & Kosmin, 2008).

Research has also been conducted on the views of scientists regarding communication; like their views on religion, norms, ethics, scientific knowledge, and success in one's scientific career, the findings of such research studies can contribute to an understanding of the beliefs that scientists share as a group. In a 2007 study by Poliakoff and Webb, researchers used the Theory of Planned Behavior to construct a questionnaire that asked about the norms, reward systems, and value systems of scientists. The researchers surveyed 169 scientists at the University of Manchester, United Kingdom, and found that time, money, and perceived career recognition were not significant constraints to participation in public engagement activities; but past participation in science communication activities, their attitude toward engagement, perceived behavioral control, and their belief of whether their colleagues participated in such activities could determine the direction and strength of their intention to participate in science communication activities (Poliakoff & Webb, 2007).

In a similar study, Tsfati, Cohen, and Gunther (2010) used the theoretical framework of the influenced of presumed media influence (IPMI) to examine why scientists collaborated with the mass media. IPMI posits that people's perceptions of the effects of mass media on others can influence how they react to the media (Tsfati et al., 2010). By surveying researchers at a top university in Israel, as well as science-related news that the researchers had been involved in, Tsfati et al. (2010) found a sense of public duty was positively associated with motivation and effort to communicate with the lay public through various multimedia channels. This meant that scientists needed to be educated about their professional obligations so that they could find the motivation to communicate (Tsfati et al., 2010).

The motivation to communicate could arise from the scientists' culture. Meyer and Sandoe (2010) examined the norm of openness in greater detail and disclosed that it should be a guide for scientists to engage in communication. The old Mertonian norms of communalism, universalism, disinterestedness, and organized skepticism (Merton, 1942) need not be done away with, Meyer and Sandoe (2010) proposed. Rather, these norms should be reinterpreted to serve the current needs of science, especially since some of Merton's norms already contain an assumption that science should be open in the first place (Meyer & Sandoe, 2010).

Riise (2008) surmises why scientists want to communicate: it may be out of “personal interest and great joy” (Riise, 2008, p. 303), as well as open dialogue with no filters or errors in translation because of mediation. On the other hand, scientists might not want to engage in communication efforts because of the time investment involved, as well as possible disapproval by their colleagues (Riise, 2008). This disapproval should come as no surprise; civic scientists are often labeled as mavericks by their fellow researchers because they have become slaves to the speed of politics and the glare of the media spotlight (Pels, 2003). Science communication may be seen as science popularization, which can cheapen the scientific profession (Gregory & Miller, 1998; Weigold, 2001) or contradict the scientific objectivity that scientists believe lends integrity to their work (Gascoigne, 2008).

These perceived benefits and disadvantages to communicating science are likewise borne out by research data. Several large scale studies have already been conducted to ask scientists about their views on science communication. Most noteworthy among them are the Wellcome Trust interviews of 2001 and the Royal Society survey of 2006. The Wellcome Trust (2001) interviewed over 1600 scientists in the United Kingdom and found that they recognized their duty to communicate their findings and the implications thereof but had no time to do so; they did not feel properly trained but acknowledged that scientists should take on the communication task themselves; and they needed encouragement from their institution, as well as funding incentives, so that they could communicate. The participants thought that funding and simple enjoyment were the greatest benefits to be gained from communicating (The Wellcome Trust, 2001).

The Royal Society (2006) surveyed over 1400 British scientists and engineers. The study found that the scientists who were most likely to communicate with the public were older than 40, with teaching responsibilities and previous communication training; and engaged in research in controversial fields (The Royal Society, 2006). This same study also revealed the researchers' beliefs about science communication: it was not approved of by the scientists' peers, took time away from research, and should not be mandatory (The Royal Society, 2006).

The organizations that scientists work for can also determine whether scientists choose to communicate. In a study of focus groups of Canadian scientists, Jacobson et al. (2004) found that knowledge transfer activities were not seen as legitimate forms of scholarship, and were thus given low priority by researchers. Universities may have encouraged their researchers to communicate, but there were no reward systems in place for fulfilling the function. These findings were echoed by a survey and focus groups of Australian researchers by Gascoigne and Metcalfe (1997). In this study, however, the researchers found that the greater the media experience of the scientists, the less likely they were to be suspicious about media activities. The scientists in the study also thought that in general, the public did not care about science, and had a negative view of scientists because scientists could not explain their work well (Gascoigne & Metcalfe, 1997).

Smaller studies have also been conducted on scientists who communicate with the public through different communication channels. Martin-Sempere et al. (2008) surveyed scientists who had worked at the Madrid Science Fair and found that communication brought the scientists personal rewards; the scientists thought that it was their professional duty to communicate; and the scientists wanted to increase the scientific culture in the public. The researchers also found that older scientists were motivated by personal commitment, while younger scientists were motivated by enjoyment and personal satisfaction (Martin-Sempere et al., 2008). Kreimer, Levin, and Jensen (2010) reported similar findings in their study of leading

Argentine researchers. They found that senior scientists were the most active in communication, and, like the scientists in Spain, communicated due to a sense of duty and a wish for a widespread scientific culture in the general public (Kreimer et al., 2010). If the scientists did not communicate, it was because of time constraints, lack of institutional support, or topics that were simply too technical to popularized and translated for the lay public (Kreimer et al., 2010).

Similar findings were also reported by Kyvik (2005), who surveyed faculty members at Norwegian universities, and who also found that most of the scientists who published for lay audiences also published their research frequently in peer-reviewed journals, despite their peers' perception of science communication acting as compensation for lack of published research. This is also corroborated by a recent survey of leading scientists in France by Jensen et al. (2008), who found that scientists who were heavily engaged in teaching, science popularization, and collaboration with industry were also the top producers of published research.

Pikas (2008) studied chemists and physicists who were also bloggers and found that they wanted to build a professional identity through their online communication efforts, and fill a gap in knowledge-sharing that peer reviewed systems had created. While they originally aimed to reach a wider lay audience, it was nevertheless their fellow scientists or graduate students who read and commented on their blog entries (Pikas, 2008).

While scientists might seem to enjoy science fairs, blogging, and communicating amongst colleagues, their relationship with the mass media is anything but peaceful. The clash between science and the mass media can be understood as a contradiction of goals and cultures. Scientists blame journalists for being nonobjective, inaccurate, and antiscientific, and journalists see scientists as stiff, unable to communicate, and dull (Gunter et al., 1999). The mass media want a story that is unexpected, unambiguous, even negative, with emotions and people's personal lives attached. This is in opposition to science, which is a validating enterprise, with much ambiguity, with often uneventful and even positive experiments, and which, as a field, discourages scientists from being mavericks by interacting too closely with the media (Gregory & Miller, 1998). The mass media can turn supposedly objective scientific reports into an appeal to the emotions (Van den Brul, 1995), or omit or add information (Weigold, 2001), much to the irritation of scientists. Scientists believe that the public lacks scientific knowledge and therefore sees scientists in a negative light (Durant, 1999), with no thanks to the media's coverage of science (Hughes, 2001).

Scientists have their own opinions on how the media should cover science news stories. For instance, when scientists involved in genetic modification were interviewed by Cook, Pieri, and Robbins (2004), the researchers found that the main concern is simplifying language for the public so that they can understand genetic modification; and if people were given the right information, then they could make the right choices. In a study by Davies (2008), scientists believed that science communication should have big ideas, fewer details, and attractive visuals – and should educate or convince people and make them understand science. Despite these apparent simplifications, one thing is certain: Science is more complex and uncertain than the mass media portrays it (Durant, 1999; Lewenstein, 1995).

Because of the small time window of the media, the complete picture of science at work, with the long process of experimentation and debates, can be lost (Gregory & Miller, 1998).

These clashes between science and the mass media are evident, to some extent, in research into the views of scientists, science communicators, and mass media practitioners. In a study of the reactions of journalists and scientists to various science-related news articles, Van den Brul (1995) found that while journalists were happy with how the news articles covered science, scientists judged the coverage as too hasty when tentative conclusions were presented. In their interviews with journalists and scientists, Gunter et al. (1999) found that scientists wanted journalists to be more objective. A similar study, this time of researchers in the European Union, found that scientists also wanted the media to educate and influence the public, and not respond to popular interests (Claessens, 2008).

Not all scientists are opposed to the media coverage of science. In a survey of Danish scientists, Neilsen et al. (2007) found that scientists had mixed feelings about the mass media's portrayal of science. The scientists in the study were split regarding their roles in communication: less than half thought that scientists should be responsible for communicating university research, a little over half thought that the responsibility should be placed elsewhere, and less than 5% were willing to share the burden with another party (Neilsen et al., 2007). In a 2008 study by Peters et al., researchers found that the risk of incorrect quotation was enough to discourage them from communicating with the public, but the researchers framed their work with the media as mainly good.

An international survey by Peters, Brossard, et al. (2008) had similar findings, in that about three quarters of the over 1,300 scientists said that they had positive encounters with the media, while only 3% considered their interaction bad. Many of the scientists who were surveyed rated the media coverage of science as neither good nor bad. The researchers attributed these findings to increased communication competence amongst scientists. Similar findings were reported by Valenti (1999) in interviews with science journalists and their sources.

Models of Science Communication

Because science communication is a complex process, several researchers have also attempted to model it. Such models can be used to classify various science communication processes, the goals of science communication, or the ways by which scientific knowledge is disseminated or shared with the lay audience.

Callon (1995) provides different models of science communication depending on how science exists relative to society. Callon's (1995) four models classify science as either rational knowledge, keeping scientific work isolated so that scientists must do their work with no interference from society; competition, where scientists use knowledge as capital and act and compete due to social pressures; sociocultural practice, where scientific work is embedded in society, so that non-scientists are seen as participants in science; and extended translation, where science is embedded in society and therefore obligated to share knowledge.

Science is conceived as sociocultural practice by d'Andrea and Declich (2005), who draw up eight major typologies to classify the different ways that science is communicated through society, whether it is amongst researchers in the same field of study (intra-epistemic communication), among researchers from different knowledge domains (trans-epistemic communication), between researchers and policymakers, between science and the lay public, or amongst laypersons. As theorized in these models, the ability and willingness of scientists to communicate their work can depend on the strength of the boundaries drawn between science and society, and how strongly scientists stand against societal influences.

Other models of science communication attempt to classify science communication in terms of the goals of the people engaged in it, as well as the technique used in communicating. For instance, Lewenstein (1995) sees science communication as a diffusion process; or an ongoing dialogue between scientists and their audience; or a way for scientists to recruit more researchers and get more funding. Gregory and Miller (1998) also provide their own models for the communication of science. Like Lewenstein's (1995) typology, their typology includes a diffusion model, but they also add a continuum model, where scientific information is sent out and received with varying degrees of acceptance; and a web model, where science communication is a complex multisector network composed of various elements of society that can contribute to how well a scientific message is received (Gregory & Miller, 1998).

Newer models of science communication consider the perspective of the lay audience as well. According to Weigold (2001), science communication models can be classified into three main types. Deficit models are centered in science: they assume that people do not have enough knowledge on science-related issues and therefore "have to know" scientific facts; if the scientists share these facts with the lay public, then the lay public can make better decisions in their daily lives, as well as appreciate and support scientific work. Rational choice models are centered in the audience: they examine what people "need to know" and then present the public with knowledge that the public needs to know at that point in time. Context models combine both anticipated audience needs and the surrounding circumstances by evaluating what people "want to know" about science based on their current situation. Trench (2008) also presented a similar typology: Trench's conceptual framework provides a means to analyze how science communication is carried out, and how scientists define science communication. Trench's (2008) framework divides different types of science communication into three principal base models: dissemination, dialogue, and conversation (Trench, 2008).

Research has shown that scientists operate largely within a deficit model. Deficit models are often criticized, especially in an age where the public is generally more alert and aware of the risks of scientific and technological breakthroughs (Schiele, 2008). However, deficit models are still being used and are not without their supporters. In particular, researchers see deficit models as ways by which scientists can be held responsible for the findings that they disseminate, simply because they are also entirely responsible for the science communication effort (Trench, 2008).

As can be seen in the models fashioned by Trench (2008), as well as Callon (1995), d'Andrea and Declich (2005), Gregory and Miller (1998), Lewenstein (1995), and Weigold (2001), scientists play a crucial role in determining if and how science communication is carried out. By understanding how scientists perceive their audience, the role that researchers play in communication, and what kind of knowledge scientists are willing to communicate and share, more effective training programs can be developed in order to assist scientists in their communication efforts.

Theory

The theory subsection is divided into two major portions. In each portion, two frameworks will be elaborated on, and then merged. The frameworks in each pair strengthen each other: each framework provides analytical power that the other framework cannot. In the first section, Science Communication Programs, Culture, and Worldviews, Trench's (2008) science communication framework will be merged with the framework of worldviews by Guba and Lincoln (1994) and a general definition of culture. In the second section, Cultural Tools and Boundary Negotiations, Swidler's (1986) model of settled and unsettled lives in a culture will be merged with an adapted version of Lam's (2010) model of science-business boundary negotiations.

Science communication programs and worldviews.

Trench's (2008) conceptual framework provides a means to analyze both current science communication activities and how scientists define science communication. This framework classifies all science communication models under three principal base models: dissemination, dialogue, and conversation (Trench, 2008):

- The base model of *dissemination* is the foundation for most deficit models. In dissemination, science is held in high esteem, defended for its doings, and marketed. In this model, scientists perceive the public as hostile and ignorant, but scientists also believe that the public can be persuaded to accept and support science. Dissemination models are also technocratic: they assume that science is the main source of trustworthy knowledge.
- The base model of *dialogue* is pragmatic and constructivist, and is likewise the basis for dialogue models. The dialogue model emphasizes context, consultation, and audience engagement. In such models, scientists see the public as having diverse needs and views. The members of the lay public act as a source of feedback, and are considered active participants in an issue. In dialogue models, scientists see the public as "them": the public provides feedback that scientists can use in their practice (Trench, 2008).
- *Conversation* models are derived from participatory democracy and relativistic practices, and are the basis for participation models of science communication. The conversation model stresses deliberation and critique, where scientists work actively with the public in shaping issues, setting the

agenda, and negotiating meanings. In conversation models, the "us" and "them" dichotomy between science and the public disappears. Conversation models emphasize "we", as scientists and the public band together to deliberate, critique, and learn from issues (Trench, 2008).

Trench (2008) argued that these models are simply different from each other, and no model is better or worse than the other. Furthermore, Trench (2008) advocated for the use of all the models depending on the nature of the knowledge being communicated and the aims of science communication.

While the Trench (2008) framework provides an excellent summary of the assumptions that communicators make when they engage in or pursue different communication programs, the framework lacks descriptive power regarding these same assumptions. This descriptive power might be derived by integrating the concept of worldviews.

A worldview encompasses how people view the nature of the world, their place in it, and the relationship of the world to its parts (Guba & Lincoln, 1994). In general, a worldview includes the following components:

- A personal *ontology* – views on the nature of reality. For example: Is there an objective reality that is separate from human sensory perception, and can therefore be measured? Or will we never know reality, and simply possess knowledge of parts of it?
- A personal *epistemology* – views on the nature of knowledge. For example: What can we know? What constitutes valid knowledge?

- A personal perception of *methodology* – views on how knowledge is obtained. For example: How do we measure reality? What constitutes a valid methodology?
- A personal *perception of the relation of the world to its parts* – views on the boundaries between science and society. For example: Is science independent of society? Should science bend to the needs of society?

There are different methods, both direct and indirect, of describing the components of the worldview. For instance, it can be difficult to directly ask what a scientist's views on reality or knowledge are. However, scientists can be asked about what they consider as valid data, how they go about getting valid data, what they define as objective science, and if they believe that objectivity is important in all scientific work.

In addition to the ontology, epistemology, and methodology components of worldviews, norms, value systems, and measures of success can also provide information on how scientists view the world. Norms, value systems and measures of success can also provide information on the culture of scientists as a group. The philosophical underpinnings of worldviews have since been used to study various aspects of scientific life, including collaborative practices amongst scientists from different fields of research (Eigenbrode et al., 2007). Worldviews can explain why scientists think and act in certain ways.

By connecting worldviews and culture to the Trench (2008) model of science communication, data analysis will involve searching for what scientists think of their audience and the nature of the information that they share. This combined framework will provide an even deeper understanding of why scientists pursue certain communication paths, and what other assumptions undergird these different communication paths. Once these assumptions are recognized, science communication can be fashioned and organized better depending on whether the model being used is classified as Dissemination, Dialogue, or Conversation.

Cultural tools and boundary negotiations.

Understanding the norms and values that make a group of scientists unique is useful in uncovering their identity as a group. However, this approach is not as valuable as looking for the phenomena that can drive action: skills, habits, and styles shaped by a culture (Swidler, 1986). In Swidler's (1986) conceptual framework of settled and unsettled lives, a culture begins in flux: it is born, shapes, and is shaped by its constituents, and finally solidified.

In an unsettled situation, people learn new modes of action and behavior because of a change in ideology. These actions are repeated until they become familiar and part of habit. This overarching ideology then becomes tradition, and then evolves into common sense.

It is in the first few years of a group's formation that culture shapes action. When lives have finally settled, the culture and the surrounding social structure can be difficult to disentangle because many of the novel activities that formed the new culture are already tradition or common sense. In other words, concepts that were once new are already taken for granted. Swidler's (1986) model claims that culture can provide people with tools that will help them deal with the world around them.

When opportunities for change arise, some people will opt not to take the opportunities because their culture might not have provided them with the tools to deal with the change. Their unwillingness to change has little or nothing to do with the cultural values that they hold. Swidler's (1986) model is therefore usually referred to as “Culture as Toolbox.”

In the language of science communication, this may mean that civic researchers feel that they have the tools, such as training in science communication, in order to share their findings with lay persons. This confidence of scientists in communication, when given the tools to do so, is borne out in various studies (Claessens, 2008; Gascoigne & Metcalfe, 1997; The Royal Society, 2006; The Wellcome Trust, 2001, to name a few). Nevertheless, the surrounding scientific culture that encompasses researchers may also play a role in dictating how researchers behave when faced with the new ideology of having to communicate their findings. This scientific culture can include norms and value systems, which are inculcated in scientists early in their academic and professional training. Norms and value systems are part of how a young scientist is socialized into the world of scientific research.

When Swidler's (1986) framework is used to characterize scientists who communicate, however, there is an implicit assumption that only one culture of the civic researcher exists. There might actually be a spectrum of involvement in science communication, ranging from scientists who completely shun the idea of communicating science, to those who consider it part and parcel of their work as scientists. It would not be enough to simply classify scientists as being in different points of the spectrum: they need to be classified according to a scheme that encompasses their norms and value systems, as well as their perception of the boundaries between scientific work and the outside world.

Lam's (2010) framework is useful in classifying researchers who are negotiating boundaries between their field and another. Lam (2010) deals with scientists' attitudes toward a research arena that is increasingly entrepreneurial and industry oriented. Lam (2010) interviewed scientists and engineers, and through the insights of participants in university-industry linkages, formulated categories of orientation toward these linkages. These categories can be influenced by early socialization and work experiences (Lam, 2010), which links the work directly to Swidler's (1986) culture-as-toolbox model.

According to the study, researchers can fall into four different groups: Tight Boundaries, Traditional Hybrids, Entrepreneurial Hybrids, and Entrepreneurial Scientists. The numbers of scientists in each group can change depending on the current financial situation, and the scientists in each group will often defend themselves against external challenges (Lam, 2010).

For the purposes of this research, Lam's (2010) framework is adopted to scientists who are negotiating the boundaries between (a) science and those tasked to communicate science and (b) science and the lay public. It is acknowledged that while researchers may wish to set boundaries between themselves and communicators, they might also wish to remove the boundaries between them and the lay public by communicating directly to the public. The researchers might also set boundaries between themselves and social scientists, a group that figures greatly in science communication; these boundaries might be different from the boundaries that scientists set between themselves and communicators.

As a result, Lam's (2010) framework will take on three forms, depending on which boundary is being negotiated. It is acknowledged that even if researchers want to communicate their findings, they might not be able to due to legal constraints. This adoption of the framework concentrates on what the researchers wish to do despite these same constraints.

When exploring boundary negotiations between scientists and science communicators, researchers may fall into one of the following categories:

- Type 1 – *Tight Boundaries* – Researchers who belong to this category work to maintain the purity of the scientific enterprise and protect it from science communicators. Involvement in science communication is seen as harmful to science, and the scientist, therefore, must not communicate. Science must remain isolated from communicators.
- Type 2 – *Traditional Hybrids* – Researchers who fall into this category test and maintain the boundaries between science and communicators. While these researchers believe in the tight boundaries, they are willing to test them if they receive benefits for their work. They may alter their research programs to accommodate feedback from science communication. They feel that scientists have a social obligation to carry out science communication work. They are willing to experiment with new roles and practices. To some extent, they feel role identity tension.

- Type 3 – *Communicating Hybrids* [in Lam's (2010) work, Entrepreneurial Hybrids] – Researchers who fall into this group negotiate and expand their boundaries. While they are committed to the norms of science, they still believe that the boundary between the world of science and science communication is permeable, where knowledge production and communication can still be combined. They do not believe that their goals as researchers are compromised because of increased public visibility, and they do not experience any role identity tensions.
- Type 4 – *Communicating Scientists* [in Lam's (2010) work, Entrepreneurial Scientists] – Researchers who fall into this group break the boundaries and link their work to communication. They are willing to alter their research programs to fit external demands. Work with science communicators is seen as a skill, but they may admit that they have a hard time keeping up with the academic side of the bargain.

When exploring boundary negotiations between scientists and the lay public, researchers may fall into one of the following categories:

- Type 1 – *Tight Boundaries* – Researchers who belong to this category work to maintain the purity of the scientific enterprise and protect it from feedback from or involvement by the lay public. The opinions of non-scientists are perceived as being harmful to science, and the scientist, therefore, must not be involved with the lay public. Science must remain isolated from any public interference.

- Type 2 – *Traditional Hybrids* – Researchers who fall into this category test and maintain the boundaries between science and the lay public. While these researchers believe in the tight boundaries, they are willing to test them if they receive benefits for their work. They may alter their research programs to accommodate feedback from the lay public. They feel that scientists have a social obligation to carry out science communication work. They are willing to experiment with new roles and practices. To some extent, they feel role identity tension.
- Type 3 – *Communicating Hybrids* [in Lam's (2010) work, Entrepreneurial Hybrids Lam's (2010) – Researchers who fall into this group negotiate and expand their boundaries. While they are committed to the norms of science, they still believe that the boundary between the world of science and the lay public is permeable, where knowledge production and communication with the public can still be combined. They do not believe that their research goals are compromised because of increased media visibility, and they do not experience any role identity tensions.
- Type 4 – *Communicating Scientists* [in Lam's (2010) work, Entrepreneurial Scientists] – Researchers who fall into this group break the boundaries and link their work to communication. They are willing to alter their research programs to fit external demands. Work with the public is seen as a skill, but they may admit that they have a hard time keeping up with the academic side of the bargain.

When the Swidler (1986) and modified Lam (2010) frameworks are used together, they can provide a broader classification scheme that will identify the nature of the boundaries that scientists place between themselves and the mass media, or themselves and the lay public. This classification scheme will also include norms, values, and cultural aspects that allow scientists to negotiate these same boundaries.

This combination of frameworks can allow for a deeper understanding of the culture of the civic researcher. First, the combination allows for an analysis of the various cultural norms of science and how they influence whether or not scientists choose to communicate. Second, the combination allows for a classification of the many types of civic researchers and how they negotiate their boundaries. Therefore, this combination of frameworks can be useful in characterizing civic researchers and their perceived role in science communication. This combination of frameworks, moreover, provides a richer portrait of the current culture of science communication through the eyes of researchers. In using these two frameworks, researchers are not alone in the science communication culture, and they may have cultural tools which not only allow them to function in the new culture, but also dictate the nature of the boundaries that they set between themselves and these other parties.

The two combined frameworks presented are also valuable in understanding civic researchers better. By using frameworks as guiding lenses, data analysis may be more comprehensive and focused, and gaps in the research may be identified.

This may contribute to the growth of theory in science communication, as well as direct future research that will further the growth of theory in this fledgling field.

The Cultural Contexts

This section of the literature review is divided into two major portions. The first portion provides historical and background information on the Philippines, and the second portion provides historical and background information on Purdue University.

The Philippines.

The Philippines is a rich cradle of biodiversity, and one of the top ten countries in the world with the most threatened endemic species (The World Bank, 2004). It is located in Southeast Asia, and is composed of 7,107 islands in between the South China Sea and the Pacific Ocean (The World Bank, 2004). Due to its colonial history, the Philippines offers a rich hub of culture, as well.

Before the 16th century, the Philippines was composed of subsistence, agriculture-based economies engaged in livestock, agriculture, and mining (Caoili, 1986). The Spanish colonists fostered the growth of modern science in the mid-1500s, but agriculture also declined due to the creation of centralized towns and cities, and education was limited to the children of Spanish families (Caoili, 1986). Higher education was perceived to be an instrument of rebellion, so classes were confined to lectures and recitation only, while laboratory equipment for science classes was kept in glass cases and used only for display (Caoili, 1986). Despite these limits, some Filipinos were able to conduct research into tropical diseases (under the Dominicans) and meteorology (under the Jesuits) in mid-19th century Manila; some scientists, doctors, and lawyers were trained either in Europe, or in local universities, some of which predate Harvard (Caoili, 1986).

After a revolution against Spain, and then colonization by the Americans, the Philippines finally developed its own public education system (Caoili, 1986). The University of the Philippines system was created in 1908, but the studies of and careers in law and medicine were favored over trades such as agriculture, which was regarded as manual labor under the Spanish (Caoili, 1986). After World War II, the Philippines was destroyed but also gained independence from the United States. In its war-torn state, the country had to deal with a damaged economy and lack of infrastructure (Caoili, 1986).

Education is still a top priority in the country today, and research is also gaining ground. Filipino researchers are working on protecting several endemic species and habitats, such as the UNESCO-protected Tubbataha Reef and the Palawan Subterranean River. The University of the Philippines System is the most developed (Caoili, 1986) and the highest ranked university in the country in terms of research and education (International Colleges and Universities, 2010; Times Higher Education, 2010).

However, there are several problems, not the least among them being research funding, lack of qualified research staff, and lack of equipment. For instance, politics determines what institutes are funded and who are placed in positions to run them (Caoili, 1986; Suarez, 2008). Due to lack of resources, the

Philippines is suffering a diaspora of science professionals out of the country and into developed countries such as the United States (Caoili, 1986; Suarez, 2008). The Department of Science and Technology has tried to control this brain drain by providing a program for returning scientists, but there is no infrastructure in place to help them find jobs (Suarez, 2008). Moreover, research funding is given to research work that has a practical component, so that project leaders often focus their writing activities in furnishing funding agencies with annual terminal reports instead of publishing their work in peer-reviewed journals (Suarez, 2008).

Nevertheless, the Philippines has found ways to lead Asia in terms of using science and technology. For instance, the country was the first to adopt Bt corn in Asia, and several local research laboratories are engaged in genetic modification work to improve fruits such as papaya and tomato (Navarro et al., 2007). Many scientists are also engaged in science communication, an activity made urgent by the protests that rose due to the adoption of Bt corn (Navarro et al., 2007).

Purdue University.

Purdue University was established as a land grant university in 1869 and is therefore mandated to carry out research, teach, and provide extension services (Purdue University, 2011). Today, the main campus in West Lafayette, Indiana, USA offers more than 200 undergraduate majors, more than 70 graduate programs, and professional degrees in veterinary medicine and pharmacy (Purdue University, 2011). The university's engineering programs are ranked 11th overall in the U.S., and

Purdue University itself is ranked 18th among all public universities in the country (Purdue University, 2011).

The university also houses a research park and extension services in every county in the state. The main campus has over 400 research laboratories and over a hundred research centers and institutes (Purdue University, 2011). In the 2006-2007 academic year, revenue and gifts for university research approached $475 million in funds from local, state and federal government, foundations, industry, and individual donors (Purdue University, 2011).

The West Lafayette campus is home to 1,918 tenure track professors, of which 1,417 are men and 501 are women; and of which nearly a fourth are ethnic minorities (Purdue University, 2011). The campus also employs 845 non-tenure track faculty and lecturers (comprising 462 men and 383 women; and 37.5% of which are ethnic minorities) and 330 adjunct faculty (comprising 258 men and 72 women; and 20% of which are ethnic minorities) (Purdue University, 2011).

Purdue University (2011) is also engaged in a number of engagement activities as part of its strategic plan, including new business development, technology transfer, business attraction and retention, P-12 education, community development, service learning and community service, and lifelong learning.

CHAPTER 3: METHODOLOGY

Research Design

This research used a phenomenological approach and qualitatively-based methods to explore how the science culture and scientific worldviews relate to the beliefs of scientists and engineers regarding science communication. Such an approach is meant provide an in-depth perspective of a phenomenon through the experiences and narratives of those who are immersed in it (Patton, 2001). In this research, the use of a phenomenological approach entailed asking: What does it mean to be a scientist? What does it mean to be engaged in communicating science?

The phenomenological approach was carried out through interviews with scientists and engineers, and using an interview protocol that was supported by the literature. Interviewing participants allowed them free rein to elaborate on their answers, and to provide answers without prompting from the interviewer (Patton, 2001; Schutt, 2009).

Both deductive and inductive analysis methods were used to analyze the data. Both these methods can provide a broader perspective as well as in-depth analysis of the phenomenon of science communication through the points of view of the participants. Deductive analysis of the data involved the use of conceptual frameworks to examine specific contents of the interview data and field notes. Such a method provides an in-depth approach by examining in detail various aspects of science practice, culture, and worldview that contribute to a phenomenon (Hatch, 2002). These conceptual frameworks were supported by and adopted from the literature. This literature-based design rooted the current research to previous research in the field in order to provide a new perspective into the phenomenon of the civic researcher, as well as the science communication itself. Inductive analysis, on the other hand, was used to describe other aspects of science practice that are not covered by the conceptual frameworks used. An inductive approach allows for a broader perspective of the phenomenon of science communication. An inductive approach can take into account other aspects of scientific work that might contribute to a more expansive understanding of science communication without being limited by the bounds of the conceptual frameworks being used (Hatch, 2002).

Moreover, the use of a phenomenological approach, research-grounded interview protocols, and framework-based analysis focused the research to answer specific research questions (Hatch, 2002; Patton, 2001; Schutt, 2009).

Design of Interview Instrument

The interview instrument was formulated and field tested in early 2009 with Ph.D. students from the Philippines. These students were selected through referrals from the officers of the Purdue Filipino Association (Purdue Filipino Association, 2009). Following referrals, four Ph.D. students were selected, who were later contacted and agreed to participate in an interview. Each student was interviewed one-on-one, simulating the atmosphere and procedures of the interviews to be conducted in this research. All interviews were conducted in their entirety, and the participants were allowed to discuss their opinions regarding the interview process, as well as suggestions for questions to be asked, changed, or reordered. Based on the field test, minor revisions were made to the phrasing and order of some interview questions.

The final, field-tested questions are presented in detail in Appendix E and Appendix F.

Each question was designed with the aim of obtaining data that would contribute to understanding the communication programs to which researchers subscribed, their worldviews, the science culture, the participants' views on boundaries between science and those who communicated science, and the participants' views on boundaries between science and the lay public. These questions were derived from previous research on elements of the scientific worldview, the science culture, the views of scientists regarding science communication, and the views of scientists regarding science education. These studies included the following: interviews with researchers regarding the rewards for research or communication by Jacobson et al. (2001); the views of female scientists by Monhardt et al. (1999); scientists' views on the nature of science by Schwartz and Lederman (2008); the views of scientists from different countries by Wong and Hodson (2009); the views of scientists regarding success by Hermanowicz (2006); scientists' views on the media by Gascoigne and Metcalfe (1997); and the philosophical components of worldviews and how they affect trans-disciplinary collaborations by Eigenbrode et al. (2007). In addition to these research articles, other research articles from the literature were used to inform how questions were phrased (Berk et al., 2000; Coll et al., 2009; Coll & Taylor, 2004; Cook et al., 2004; Davies, 2008; Falcão, 2008; Harwood, Reiff, & Philippson, 2002; Poliakoff & Webb, 2007; Varma, 2000; Zeldin & Pajares, 2000).

The interview questions were framed with the intention of addressing several issues and informing several frameworks by asking one question. As a result, any individual framework is constructed from multiple answers. Therefore, the answers to individual questions do not lend themselves to interpretation and presentation through descriptive statistics; for these items, answers must be interpreted in the context of the entire interview.

The interview instrument opened with several questions to make participants more comfortable and thus discuss their ideas more freely. These “ice breaker” questions included demographic questions: participants' age, marital status, the highest level of education they completed, where they completed their highest level of education, their field of expertise, the nature of their current job, and why the participants pursued their current field of study. These opening questions, often referred to as “grand tour questions” in the literature (Schutt, 2009), serve to engage interviewees in the specific topic. The items were meant not only to ease the participants into the interview process, but to encourage discussion of participants' personal experiences into how they were socialized into their specific field of research. Thus, the participants' answers could also contain elements of the participants' worldviews and their views of the science culture.

The next set of questions addressed the participants' perceived image of themselves as researchers. The participants were asked about the importance of mentors, the responsibilities of researchers, the job of a researcher, characteristics of successful researchers, how success was measured, how to succeed in research, how not to succeed in research, and how the participants formally defined a scientist or engineer. The answers to these questions were meant to provide the following information: how the participants were socialized into science or engineering; and their opinions on the nature of the scientific enterprise, the science culture, the norms and value systems of science, the reward and punishment systems of science, and the ideologies that science espouses.

The next set of questions addressed the participants' views of the nature of science. The participants were asked about their views of science as they learned it in school versus the perspectives they gained in the professional world; the responsibilities of science as a field; the participants' views on the social sciences; and the participants' views of what was *not* science. The answers to these questions were meant to contribute to an understanding of participants' worldviews, how their current views of science compare with those into which they were socialized, what constitutes valid scientific knowledge, and the culture of science.

The next set of questions explicitly dealt with the participants' views of the scientific culture. The participants were asked about the culture of scientists or engineers, depending on what field the participants were working in. The participants were asked about their background culture and how it affected their work, what other aspects of their lives or philosophies affected their work, their views on the public perception of scientists or engineers, the participants' lives outside the laboratory, and how their life outside the laboratory affected or informed their research. The answers to these questions were meant to contribute to an understanding of the science culture, the boundaries that researchers may set between their work and the outside world, their views on the mass media, and the cultural tools that science provides for researchers to deal with changes in the research culture. In these questions, the terms “mass media” were drawn into the questions in order to prompt participants to provide opinions on the mass media.

The next set of questions was meant to elicit the participants' views on the nature of scientific inquiry. The participants were asked about the data and methods that they consider scientific, what makes scientific work unique, the methods that they use to gather data, their views on the work that social scientists carry out, and their views on objectivity. The answers to these questions were meant to provide information on the participants' worldviews and their perception of the science culture.

The next set of questions was concerned with science and risk communication. The participants were asked to define risk communication and science communication, the goals of both kinds of communication, and what the participants believed their role was in communication. This entire section was meant to contribute to an understanding of the communication programs that researchers subscribe to, their perceived boundaries between scientists and those who communicate science, and their perceived boundaries between scientists and the lay public.

The next set of questions focused exclusively on religion. The participants were asked about their religious beliefs and if these religious beliefs affected their work. This section was meant to contribute to an understanding of the participants' worldviews and the science culture.

At the conclusion of the interview, participants were invited to provide feedback on the interview. Feedback questions included asking participants to assess the interview, as well as to voice other concerns or opinions that had not been addressed in the interview itself. Their feedback could be used to further understand the participants, as well as provide recommendations for future research.

Data Collection in the Philippines

The initial phase of this research was carried out in the Philippines. Twenty (20) participants were recruited and interviewed using the methods outlined below. All participants were interviewed in locations of their own choosing. Field notes were also taken before and after each interview in order to describe participants and disclose biases of the researcher.

Selection and recruitment of participants.

Participants from the Philippines were recruited by searching through online directories of researchers, which were available at the main and adjunct websites of the Philippine-American Academy of Science and Engineering (http://www.paase.org/memberlist.htm) and the University of the Philippines (http://www.up.edu.ph). Both of these directories were selected because they were publicly available sources of contact information and because they contained the names of researchers who held academic and/or administrative appointments, and were still actively involved in research. Only researchers who were working in the bench sciences (natural sciences, physical sciences, and mathematics) and engineering were selected. The names of a total of 153 possible participants were gathered from the lists available on the websites. According to the descriptions provided on the websites, all of the 153 persons in the sampling frame held doctoral degrees in the bench sciences and engineering, were active in research, and had teaching experience or were still teaching. This list of 153 possible participants was arranged alphabetically by last name, and each person was assigned a number.

From these lists, a total of 20 potential participants were randomly selected using systematic random sampling in order to obtain an even distribution across research disciplines and experience. A contingency list of 20 more randomly selected persons was also made, and using another random number. This was carried out so that should any of the original 20 possible participants refuse to be interviewed, they were easily replaced by another from the contingency list. In case any persons were sampled again, the person immediately following them on the list was selected. The aim was to interview a total of 20 participants. The numbers of participants is based on average research figures: Coll and Taylor (2008) interviewed 18 scientists; Harwood et al. (2002), 52; Monhardt et al. (1999), 18; Schwartz and Lederman (2008), 24; and Zeldin & Pajares (2000), 20.

A recruitment e-mail was sent to the potential participants, which is presented in Appendix A. The potential participants were given 2 weeks to send a reply through email. If the potential participant consented through email, a scheduling and introduction letter were also sent, which is presented in Appendix B. If the potential participant did not reply within 2 weeks, a follow-up email was sent. If there was still no reply from the potential participant, then the contingency list was consulted for a replacement. If the contingency list was exhausted and the quota of 20 participants had still not been reached, then another pass of systematic random sampling would be conducted on the data set, using another random number. In case any persons from the previous passes were sampled again, the person immediately following them on the list was selected.

Interviews with participants.

Participants were emailed personally and meeting times were negotiated with the persons to be interviewed. Interviews were held at a place of the participants' choosing and convenience. It was assumed that the participants would be busy with laboratory or administrative duties, and therefore would not want to be interviewed at work. Allowing participants to choose their own interview location would increase as well as enhance participation.

The researcher alone had access to the email addresses and email exchanges with participants. Once a participant had consented to an interview, he or she was assigned a pseudonym. This pseudonym was used throughout the data collection, analysis, and reporting process. Only the researcher had access to the code list containing the names of the participants and their corresponding pseudonyms.

Because the interviews were meant to be conversational and not interrogatory, the researcher asked participants the interview questions in different orders each time, depending on the direction of the conversation. Nevertheless, all participants were asked the same questions in the same manner, and clarifications were encouraged if the participants did not understand the questions. Participants were also offered the option to not answer questions, terminate the interview when they wanted to, or to go off the record. All interviews were recorded with a digital voice recorder. The interviews were conducted in the Philippines in the months of July-August 2009. The questions for the Philippine-based group of participants are presented in Appendix E.

The interviews were transcribed by the researcher, and once the transcriptions were concluded, all recordings were destroyed. Because some participants spoke in a mixture of Filipino and English, the researcher translated their interviews. These translated interviews were then used for data analysis.

Data Collection in the United States

The second phase of data collection for this research was conducted in the United States at Purdue University, West Lafayette, Indiana. While the population of the U.S. group was not spread out over various locations, it was still concentrated at a land-grant university, which carries out extension work. What are relevant are the experiences of the participants as they worked within the American cultural milieu. Twenty (20) participants were recruited and interviewed using the methods outlined below. All participants were interviewed in locations of their own choosing. The researcher also took field notes before and after each interview in order to note observations about the participants, as well as disclose researcher biases.

Selection and recruitment of participants.

The researcher, along with a student assistant, searched through the Purdue directory, available online through http://www.purdue.edu. The search was limited to full-time faculty members of the bench sciences (natural sciences, physical sciences, and mathematics) and engineering, and who belonged to the bench science and engineering departments of Purdue's Colleges of Agriculture, College of Science, College of Engineering, College of Pharmacy, School of Veterinary Sciences, and the Interdisciplinary Life Sciences Program. The information is publicly available.

The names of 1,018 potential participants were collected and arranged alphabetically into a single master list. According to the descriptions provided on the websites, all of the 1,018 persons in the sampling frame held doctoral degrees in the bench sciences and/or engineering, were active in scientific research, and had teaching experience or were still teaching. This list of 1,018 possible participants was arranged alphabetically by last name, and each person was assigned a number.

From these lists, a total of 20 potential participants were randomly selected using systematic random sampling in order to obtain an even distribution across research disciplines and experience. A contingency list of 20 more randomly selected persons was also made, and using another random number. This was carried out so that should any of the original 20 possible participants refuse to be interviewed, they were easily replaced by another from the contingency list. In case any persons were sampled again, the person immediately following them on the list was selected. The aim was to interview a total of 20 participants. The numbers of participants is based on average research figures: Coll and Taylor (2008) interviewed 18 scientists; Harwood et al. (2002), 52; Monhardt et al. (1999), 18; Schwartz and Lederman (2008), 24; and Zeldin & Pajares (2000), 20.

A recruitment e-mail was sent to the potential participants, and is presented in Appendix C. The potential participants were given 2 weeks to send a reply through email. If the potential participant consented through email, a scheduling and introduction letter followed, which is presented in Appendix D. If the potential participant did not reply within 2 weeks, a follow-up call was made to the potential participant's office using the publicly available phone numbers listed in the Purdue directory. If the potential participant did not consent to an interview or did not return calls after three attempts by the researcher, then the contingency list was consulted for a replacement. If the contingency list was exhausted and the quota of 20 participants had still not been reached, then another pass of systematic random sampling would be conducted on the data set, using another random number. In case any persons from the previous passes were sampled again, the person immediately following them on the list was selected.

Interviews with participants.

The researchers emailed participants personally and negotiated meeting times with the persons to be interviewed. Interviews were held at a place of the participants' choosing and convenience. Participants might be busy in their laboratories and might not want to be interviewed at work; allowing participants to choose the interview location was meant to increase as well as enhance participation. Only the researcher had access to the email addresses and exchanges. Once a participant has consented to an interview, he or she was assigned a pseudonym. This pseudonym was used throughout the data collection, analysis, and reporting process. Only the researcher had access to the code list containing the names of the participants and their corresponding pseudonyms.

Minor changes were made in how the interview questions were phrased in order for the interview questions to be more appropriate to the U.S. setting. In the first instance, instead of asking participants to think of the scientific culture in terms of various aspects that hold Filipinos together as a culture, the participants were prompted to think of how various persons belong to different cultures. Second, instead of saying how there are only a few Filipino scientists, the participants were prompted by being told that the term "scientist" is used loosely in the public arena, but is not always defined. The questions for the Purdue group of participants are presented in Appendix F.

Because the interviews were meant to be conversational and not interrogatory, the researcher asked the participants the interview questions in orders depending on the direction of the conversation. Nevertheless, all participants were asked the same questions in the same manner, and clarifications were encouraged if the participants did not understand the questions. Participants were also offered the option to not answer questions, terminate the interview when they wanted to, or to go off the record. All interviews were recorded with a digital voice recorder. The interviews took place between the months of October 2010 and January 2011.

The interviews were transcribed by an external transcriber. Once the transcriptions were proofread, all audio recordings of the interviews were destroyed.

Data Analysis

Data analysis was carried out in two major phases, with protocols taken from Hatch (2002). First, deductive analysis was used to categorize responses according to the theoretical and conceptual frameworks being used in this research. Second, inductive analysis was used to categorize responses that did not necessarily fall into the theoretical and conceptual frameworks, but were still considered consequential to answering the research questions. The data consisted of a total of 40 interviews and 40 sets of field notes.

Deductive analysis.

Deductive analysis was carried out using typologies from the literature. These typologies corresponded with various aspects of the conceptual frameworks that were used for this study. These typologies were defined according to what the researcher must search for when coding the data.

The typologies are presented below according to the analysis scheme outlined in the theory section of this document. These typologies are presented in their most complete form in Appendix G, and are consolidated as the Code Book. There are repeated as well as overlapping typologies. This was used to ensure that the coding was done accurately. Only one researcher was carrying out data coding, so these overlaps and repeated typologies served as internal controls to check if the researcher was coding portions of the interview under the same typology no matter where that typology was in the overall codebook.

1. Science Communication Programs and Worldviews

- The nature of science
    - The nature of science as imposed by school/academe
    - The "real" nature of science, which may be based on the scientist's opinion
- The nature of scientific inquiry
    - The nature of science as imposed by school/academe
    - The "real" nature of science, which may be based on the scientist's opinion
- The scientific culture
    - Norms of science
    - Measures of success
    - Values of science
    - Sanctions and prohibited activities
- Science and society
    - The responsibilities of science and researchers
    - Should science be free from these influences of society?
- The researcher
- Science and the surrounding culture
    - Cultural habits of the surrounding culture
    - Funding

    - Politics and economics
    - Religion
- The nature of scientific knowledge
- The image of science
- The role of researchers
- The image of the public
- How to communicate science well despite the issues
- The role of science communication

2. Cultural Tools and Boundary Negotiations

- The overarching ideology
- The scientific culture
- The new ideology
- The science communication culture
- Tools
- Traditions and common sense
- Competition with existing cultural assumptions
- The nature of the mass media
- The responsibilities of researchers
- The responsibilities of science
- Boundaries between mass media and science
- Boundaries between the public and science
- Boundaries between the mass media and the public
- Boundaries between the social and bench sciences

- Effects of mass media on science/engineering research
- Effects of mass media on the lay public
- Effects of mass media on the researchers themselves
- Objectivity
- The effects of external forces
- Constraints on communication
- The Roles that researchers should play

The researcher read through the data set and marked where the typologies were addressed. Because the interview questions had each been framed to address more than one framework, the participants' answers were expected to be coded under more than one typology. Summaries of the participants' answers and marked field notes were also placed into various spreadsheets, with each spreadsheet corresponding to one typology. This allowed the researcher to organize findings. In this manner, each typology could be read easily and summarized.

When the entire data set was coded according to the typologies presented in Appendix G, the researcher then read the ideas under each typology and organized the ideas into overarching themes. All ideas were considered valid, even if only one participant voiced the idea. The researcher then returned to the interviews and field notes and recoded the already marked portions of the data according to these overarching themes. These recoded portions of the data were transferred to the spreadsheets under each overarching theme.

The researcher then searched for relationships across the overarching themes, and used these relationships in order to formulate generalizations that addressed the research questions. The researcher then used these generalizations to search for representative quotations from the data in the spreadsheets, and used these quotations to support the generalizations. In some cases, participants were asked to define a term, or were asked to provide their views on science communication, risk communication, social scientists, the social sciences, and the interview process itself. In these cases, tallies were taken of the participants' responses.

However, if there was disconfirming interview data, this interview data was also considered to be part of the generalization and used to illustrate an exception. Every participant's opinion was considered valid, and quantification of responses was not an issue.

Inductive analysis.

Because not all the interview data would fit into the typologies derived from the conceptual frameworks, the researcher also conducted inductive analysis based on protocols from Hatch (2002). Inductive analysis involved rereading the interview transcripts for data that had not been coded or did not fall into the conceptual and theoretical frameworks used in deductive analysis.

First, the researcher reread the data and searched for frames of analysis: these were data that appeared significant, were repeated throughout the data set, or presented intriguing avenues for future research. The researcher created domains based on semantic relationships found among the frames of analysis. The researcher used these domains to code the data. The researcher looked for both confirmatory and disconfirming data for each domain. All of the participants' responses were considered valid, and quantification was not an issue. The researcher analyzed each domain, searched for themes across the domains, and then created a master outline that expressed the relationships within and among domains. The researcher selected excerpts from the data to support the elements of the master outline.

Data Reporting

To document the outcome of this study, the researcher will present direct quotations from the interviews, as well as feedback and reactions from participants, and use them to support generalizations made about the models of science communication, scientific worldviews, a culture of unsettled lives, and the boundary-straddling culture of science communication.

The Results chapter of this document will contain a list of the research questions, and the generalizations that address each of the research questions. The Results chapter will also contain tallied responses of the participants' views regarding science communication, risk communication, the social sciences, social scientists, and their feedback to the interview.

The Discussion chapter of this document is divided into three major portions: a discussion of the findings from the Philippine participants, a discussion of the findings from U.S.-based participants, and an overall discussion. The first two sections will contain the generalizations that address each of the research questions. Each generalization will be supported by direct quotations from the data, and a discussion of the quotations. This is to ensure that the quotations from the data are discussed within their proper context. This discussion of generalizations will be followed by a discussion of how the frameworks used can be combined in order to achieve a more detailed portrait of the participants of this study.

Because not all the participants agreed with each other or presented a uniform view on various issues addressed by the interview questions, their pseudonyms will be enumerated according to the opinions that they hold. As mentioned above, all participants' views are considered valid, and quantification is not an issue.

Limitations of Methodology

Because this research relies on data from interviews and field notes, there may be aspects unique to scientific work that cannot be covered by the frameworks. These aspects might be unique to the practice of scientific or engineering work in the laboratory, but no observations of laboratory work were conducted. These aspects might be unique to the interactions amongst scientists and engineers, whether at a conference, laboratory meeting, or research seminar. No observations of such interactions at such events were made.

Because this research relies on the use of four frameworks related to culture, there might be other aspects of science culture that cannot be documented because they are not covered by the frameworks being used. Moreover, the interview instrument was based on the frameworks, so there might have been questions that should have been asked but were not in the literature or were not covered by the frameworks.

Threats to Validity and Measures to Ensure Validity

The qualitative research paradigm has its own definitions of research validity and reliability. Internal validity measures the accuracy of the instrument of the research, the researcher herself. Reliability is measured through whether the results are consistent with the data collected. External validity relies on concrete universals. This research aims to "understand the particular in depth, rather than find out what is generally true of many" (Merriam, 1995, p. 57).

To ensure internal validity, or accuracy of the instrument of the research, the researcher triangulated methods (Guba & Lincoln, 1994). Method triangulation was carried out by analyzing interview as well as field notes, and using more than one source of data by interviewing forty participants from different research fields and two different cultures (Schutt, 2009). This triangulation of methods was ensured throughout the course of data collection and analysis by formulating a "Role of the Researcher" statement, writing field notes, and documenting insights and research findings using thick descriptions.

To ensure validity of the interview instrument, the researcher field tested the interview questions with several Ph.D. students from the Philippines who were near graduation from their programs. The interview questions were refined and modified through their clarifications on the questions and suggestions on how questions could be asked.

To ensure validity of the interview sessions, the researcher took care not to offer or accept gifts from interview participants, or to disclose any of the interview questions in-depth prior to the interview (Schutt, 2009). If participants asked for the interview questions before the interview, they were given the summarized, general themes that are presented in Appendices B and D. The researcher also fully informed participants on the nature of her research and assured them that their names and identities would be kept confidential. The researcher allowed participants free leave to reschedule the interview, refuse to be interviewed, change venues, ask for clarifications on questions during the interview, and go off the record. Although participants were not asked the questions in the same order each time, the researcher ensured interview validity by retaining the format of the questions being asked. The change in question order was a method to ensure that the interview flowed smoothly, and in order to make participants feel that they were engaged in a conversation rather than an interrogation (Schutt, 2009). This method resembles “intensive interviewing” (Schutt, 2009) in that it allows participants to provide their own definitions to terms, and answer open-ended questions out of order in order to provide a more comprehensive picture of an interviewee’s background.

The validity of the interview data was ensured through a second check of transcripts while listening to the audio recordings of the interviews. Translations of the Philippine interviews could not be checked by an external source, but because minimal translation was needed, this was not considered a threat to data validity.

Validity of data analysis was ensured through embedding duplicate typologies within the codebook to ensure that the researcher was coding the same statements in the same ways. As the researcher read through the data, she avoided making value judgments by creating tallies of answers that participants agreed on, but also took care not to exclude contrary points of view that some participants espoused. In this manner, no overgeneralization or overconclusion was made that would remove the views of some participants, even if they were the minority.

Validity of data analysis was also ensured through avoiding comparisons between Filipino and U.S. scientists before the research was carried out, during research, during interviews, during data analysis, and in writing the dissertation document. This was carried out by retaining the interview protocol, with minor adjustments to account for cultural nuances in either culture. This was also done by analyzing data in sequence rather than together, and by using the same frameworks and typologies to analyze both data sets from both cultures. The complete results of analysis were written down in sequence as well in order to avoid making any comparisons even while the document was being written. A comparison might skew data, force uniqueness where there was none, or force unity between cultures where there was none.

To enhance the credibility of the research findings, the researcher uses low-inference descriptors. These descriptors are in the form of verbatim responses from the interviews and direct quotations from the interview data, both of which are meant to reproduce the participants' responses as closely and accurately as possible (Ary, Jacobs, Razavieh, & Sorensen, 2006; Rubin & Rubin, 1995). These low-inference descriptors are used to support the generalizations made in this research.

Finally, validity of data analysis was ensured through constant collaboration and consultation with the researcher's major professor. This was undertaken in order to guarantee that the researcher was not overconcluding from, overinterpreting, miscoding, or misunderstanding the data.

The Role of the Researcher

I have always been a scientist and communicator as far back as I can remember. I loved working on things on my own: I loved tinkering with toys, playing with home laboratory kits, and reading about the natural world. I also loved to communicate: I wrote poems and short stories, I enjoyed writing novels, and I took pleasure in debating and talking in public. I did not think that both these loves would one day be united in science communication. As a trained bench scientist, I had once been told that science and communication were truly two separate worlds, and never the twain would meet.

As a researcher of molecular biology, I was not aware of the culture of science until I stepped out of the laboratory and began to talk to teachers, students, farmers, local government officials, and even activists about biotechnology. I thought that I could convey any idea I so pleased, and that I had the gift of contaminating anyone with my enthusiasm. However, I was shouted at by members of farmers' groups, derided by Greenpeace, and even chided by my fellow scientists for communicating with the public. I could not understand why communicating, which I enjoyed, was contradictory to scientific work. I decided to pursue the unpopular path of science communication: a field that put together two of my passions, but which apparently was on the borders of two fields that were not exactly friendly with each other.

As I look back on my journey as a researcher, I also see how I was a technocratic scientist straddling the fence between the social and bench sciences. I thought I had all the ideas, education, and intelligence to carry me through any communication. I had even been taught to look down on the social sciences, and I had been made to think that being a social scientist was easy. As I studied the field of science communication more, I also realized that I had been arrogant: the natural sciences did not have all the answers to pressing questions in society, and there was so much left unknown, undertheorized, and unexplored ground in science communication.

To illustrate: I first came with the mission to make science communication "better" (a word that I could but define vaguely) so that society would listen to scientists. Dr. Austin Babrow, my professor in risk communication at the time, and a former faculty member of the Purdue University Department of Communication, promptly asked my *why* people needed to learn science at all. I insisted that science was important to national progress, and that society could move forward with science. Dr. Babrow promptly questioned my reasoning, and kept on asking me "why" until I quit answering in both irritation and exasperation. It was only later that I realized that Dr. Babrow's method had uncovered my own biases as a researcher; his method had showed me what was standing in the way of my own research. His questions had unearthed my arrogance as a scientist, and my paternalistic view of the world outside scientific research.

I came to this university as a Ph.D. student who thought she knew everything. I slowly realized I knew nothing.

It was from nothing, therefore, that I had to begin.

Thus began my journey to formulate my final dissertation questions. I read as much literature as I could so that I could see what science communication lacked, what the future held for it, and what participants thought it was for. As I read through the research, I tried to find a place to root and establish my own work.

As I read, I also found that I had a question in my mind ever since I had begun to explore science communication. I had always asked why scientists thought about communication in certain ways, and why it was so difficult for them to communicate to the lay public. With further reading, as well as debates and discussions with Dr. Mark Tucker, I finally arrived at a topic that filled a void in the science communication literature, and answered my own pressing questions as well. How did scientists from two different cultures conceptualize their science, and how did their science cultures and worldviews influence the science communication models to which they subscribed? I decided to interview 20 participants each from Purdue and my native Philippines, a task I thought would be easy in both execution and analysis.

As I learned, however, there was no such thing as a simple task in qualitatively-based research. I needed to confront my own biases and fears. As a Filipino, I was afraid that I was coming home as an outsider to science, because I had always been taught that the social sciences were inferior to the bench sciences. I was afraid that being an international student would make me less credible as a researcher to my U.S.-based participants. Nevertheless, I had questions that I wanted answered, so I decided to pursue my research. I was as cordial, and yet respectful as possible to all my participants. Whether they looked down on me, I will never know; I simply did my best to be as friendly and open an interviewer as possible.

The reward for my openness came in the form of compliments from participants, as well as personal stories they shared generously with me. Participants talked about how they wanted to help people, how frustrated they were about scientists who did everything for the money, and how they loved their science so much they could not imagine doing anything else. On the other hand, participants also shared how they were struggling in their personal lives, how they labored to get funding, and how they had even been silenced forcibly by politics and economics because people needed money, while they wanted to be true to their science – while they wanted to be honest. I heard stories of personal heartbreaks and career triumphs. I heard stories as I had never heard them in my years as a molecular biologist.

As I interviewed my participants, and as I finally sat down to write my dissertation, I also realized that I had a great responsibility: I was a bridge between the bench sciences and the social sciences. Some participants had asked me to keep going in my research, to keep making communication "better" (their definition of "better" was focused on turning all non-scientists into scientists), whether it was because Filipinos did not know enough science or Americans were anti-intellectual. I discovered how passionate I was about both science and communication, but I also realized that I had to step back and let the participants tell their stories.

I analyzed data largely on my own, with consultations with Dr. Tucker. I am operating from a post-positivist perspective, and I am therefore assuming that I will only be able to approximate reality. I am also using data gleaned from field notes and interviews from two cultures so that I can triangulate my findings. I have also installed several internal controls in my code book to ensure that I was labeling interview data in the same way at different times, and for different frameworks.

I will admit that qualitative analysis was emotionally draining: I did my best to avoid making value judgments on my data, which I achieved by creating tallies of answers that participants agreed on, but without excluding contrary points of view that some participants espoused. I also avoided making comparisons between the U.S. and Filipino scientists before I carried out my research, during my research, during my data analysis, and in writing my findings. I wanted to avoid skewing my data, forcing uniqueness where there was none, or forcing unity between cultures where there was none.

In writing this dissertation, I cannot hope for generalizations to all scientists. What I can hope for is that my work will meet the need for theory in science communication. Theory allows us to ask “why” and to find out “what” contributes to a phenomenon. I hope that in the future, researchers like me will truly ask why and know how to get their answers.

CHAPTER 4: RESULTS

This section of the dissertation is divided into two major subsections: Findings from the Philippines, and findings from the United States. Both sections contain the following information: tables summarizing information on the participants of the study; tables presenting the generalizations addressing the research questions, along with tallies of participant responses, where applicable; and tables presenting participant responses to questions on science communication, risk communication, the social sciences, social scientists, and interview feedback.

Because not all individual questions lend themselves to interpretation using descriptive statistics, only the generalizations will be presented here. Answers to individual questions cannot always be tallied, and are therefore not tallied in this chapter because many of the answers to the questions address more than one aspect of a framework, as well as more than one framework. Because this research takes a phenomenological approach to understanding scientists and their perceived roles in science communication, quantification is not an issue and all participant responses are considered valid. Quantification is used in this research document as an organizational tool.

However, there are some questions whose responses can be presented in tally form. These questions pertain to the participant's views on science communication, risk communication, the social sciences, social scientists, and the interview process itself. There are also some aspects of the frameworks that can be tallied according to participant responses. These aspects include the norms, values, and sanctions of the science culture.

The tallies and tables presented will provide only frequencies of the answers given by the participants. These frequencies will not always equal the total number of participants, because some participants gave more than one answer to some of the questions.

In the next chapter, the Discussion, the generalizations will be supported with direct quotations from the data and a discussion of these quotations in context.

Findings from the Philippines

This subsection presents findings from data gathered from participants in the Philippines. This section is divided into three major portions: information on the participants, results of deductive analysis of the interviews and field notes, and results of inductive analysis of the interviews and field notes. The results of both deductive analysis and inductive analysis will be presented as generalizations that answer the research questions individually. These generalizations will be supported by direct quotations from the interviews and field notes, as well as a discussion of the quotations.

Basic information on participants.

Of the 153 potential participants, 75 were female and 78 were male. Of the 153 potential participants, 19 were from the engineering field, while the rest were from the bench sciences and mathematics. In total, 53 potential participants were requested to participate in the study after three passes of systematic random sampling. Of these 53, 31 were female and 22 were male. Of these 53, 7 were from the engineering field, while the rest were from the bench sciences and mathematics. From the 53 potential participants, 20 ultimately agreed to participate in the research. This met the requirements of this research, which aimed to interview 20 participants. Of these 20 participants, 12 were women, and 8 were men. Each participant was assigned a gender-appropriate pseudonym using names common to Filipinos: Alberto, Benigno, Carlos, Dina, Eva, Flora, Glenda, Hipolito, Isabel, Julia, Kampo, Lapid, Marina, Nadia, Ofelia, Pedro, Quirino, Rita, Sarah, and Tanya. Descriptive characteristics of Filipino participants are presented in Table 4.1.

The 20 participants were between 36 and 67 years of age (Table 4.1). Fifteen (15) were bench scientists, 4 were engineers, and 1 was a mathematician with dual appointments in the College of Science and College of Education of her branch of the University of the Philippines (Table 4.1). All of the participants worked in the academe, except for 1 participant who was a scientist with an international research organization based in the Philippines.

Fourteen (14) of the participants were still married. One (1) participant's marriage had been annulled. The 5 other participants were unmarried. Fourteen (14) participants had children (Table 4.1).

Six (6) participants reported receiving their doctoral degrees in various universities in the Philippines, 5 reported receiving their doctoral degrees from various universities in Australia, 5 reported receiving their doctoral degrees from various universities in the United States, 3 reported receiving their doctoral degrees

Table 4.1:

Descriptive Characteristics of Filipino Participants

Pseudonym	**Age**	**Gender**	**Field**	**Specialty**	**PhD Origin**	**Marital Status**
1. Alberto	49	Male	Natural Sciences	Geology	Japan	Married, 3 children
2. Benigno	48	Male	Engineering	Civil Engineering	Japan	Married, 2 children
3. Carlos	57	Male	Engineering	Marine Engineering	U.S.	Married, 4 children
4. Dina	56	Female	Natural Sciences	Immunology	Australia	Single
5. Eva	43	Female	Natural Sciences	Developmental Biology	Japan	Married, 2 children
6. Flora	55	Female	Mathematics	Mathematics/Education	Philippines	Married, 6 children
7. Glenda	45	Female	Engineering	Electrical Engineering	U.S.	Single
8. Hipolito	51	Male	Natural Sciences	Marine Ecology	Australia	Married, 1 child
9. Isabel	41	Female	Natural Sciences	Biochemistry	Germany	Married, 1 child
10. Julia	55	Female	Natural Sciences	Molecular Biology	U.S.	Single
11. Kampo	44	Male	Natural Sciences	Genetics	Philippines	Married, 6 children
12. Lapid	56	Male	Physical Sciences	Chemistry	U.S.	Married, 2 children
13. Marina	67	Female	Natural Sciences	Biochemistry	U.S.	Single
14. Nadia	47	Female	Physical Sciences	Chemistry	Australia	Married, 2 children
15. Ofelia	41	Female	Natural Sciences	Molecular Biology	Australia	Married
16. Pedro	36	Male	Engineering	Mechanical Engineering	Philippines	Married, 2 children
17. Quirino	58	Male	Natural Sciences	Biology	Philippines	Single
18. Rita	51	Female	Physical Sciences	Chemistry	Philippines	Married, 5 children
19. Sarah	58	Female	Natural Sciences	Marine Biology	Philippines	Annulled, 3 children
20. Tanya	54	Female	Physical Sciences	Chemistry	Philippines	Married, 5 children

from various universities in Japan, and 1 reported receiving a doctoral degree from a university in Germany (Table 4.1).

Interviews with the participants ranged in duration from 40 minutes to 2.5 hours. All interviews were conducted in the participants' offices, except for one participant, who was interviewed in the researcher's hotel room. All of the interviews were completed. Five (5) participants asked to go off the record due to the sensitivity of their replies.

Because participants often spoke in a mixture of Filipino and English, the researcher translated the interviews. The interview data analyzed and presented in this document are the results of translation. In terms of data presentation, an ellipsis (…) is used to indicate that words were omitted for clarity. The designation *[sic]* is inserted where participants' unedited quotations are used that could contain grammatical or other structural errors.

Results of deductive analysis.

The Deductive Analysis subsection will provide answers to the research questions of this study by presenting generalizations derived from the patterns and themes in participants' responses to the interview questions. These generalizations will be supported by tallies of participant responses, where answers to questions can actually be tallied. These generalizations will be supported by a discussion and direct quotations from the data in the next chapter.

The last research question, however, which involves data not addressed by the conceptual frameworks used to guide this study, will be answered in the Inductive Analysis section.

How do the participating researchers define science communication?

To answer this research question, the researcher tallied participants' answers to the questions involving science and risk communication in the interview. These questions asked the participants for a definition of science communication, of risk communication, the aims of science and risk communication, and the role of scientists in science and risk communication. Some of the tallies for the various answers given total more than twenty, since some participants presented lengthier answers that contained more than one element in the total response pool. Responses are summarized in Table 4.2.

When asked to define science communication, 13 participants defined it as providing accepted and valid scientific information to the lay public (Table 4.2). Three participants each had different definitions of science communication: a means to talk to politicians about the importance and significance of scientific work, a practical way of communicating research findings to non-scientists, and a way to advocate for science (Table 4.2). Four (4) participants did not know or could not define what science communication was (Table 4.2).

When asked about their perceived function of science communication, 5 participants believed that science communication was designed for the lay public to appreciate and, consequently, accept science (Table 4.2). Five (5) participants believed that science communication was meant to engender scientific thinking on the part of the lay public and to make people think and reason the way that scientists did. Another 4 participants believed science communication had an

Table 4.2:

Summary of Communication Definitions of Philippine Participants

Concepts	**Science Communication**	**Risk Communication**
Definition	Provide information to lay public (13) Communicate with politicians (1) Practical way of communicating research (1) Advocacy (1) Don't know (4)	Explain risks to people (6) Explain risks in context (2) Proactive way to communicate and warn (1) Explain risk to government officials (1) Don't know (10)
Aim of Communication	Appreciate and accept science (5) Engender scientific thinking in lay public (5) Build up knowledge (4) Change people's minds and behavior (2) Get feedback (2) For people to respond properly to issues (2) Save people in times of crisis (1) Provide means for scientists to talk directly to people (1) Increase funding (1)	Understand risk of technology (8) Know the truth about risks (3) So that people know what to do in times of crisis (3) Should not be done (2) Prevent panic (2) Save people (1) Get funding (1) Don't know (2)
Role of Researcher	Communicate directly (12) Work as information providers/consultants (5) Communicate only if capable (3)	Communicate directly (11) Work as information providers/consultants (5) Communicate only if capable (3) Do not communicate at all (1)

education function, and was a way for more people to know science or to build up their science knowledge. Two (2) participants believed that science communication would change people's minds and behavior in times of crisis, and allow them to make science-based decisions. Another 2 participants believed that science communication should communicate the truth about science. Another 2 participants believed that science communication was a way for researchers to get feedback on how the public defined its problems, and this feedback could be used to start new research projects or modify existing ones. Another 2 participants thought that science communication would make people respond properly to science-related issues. Three other participants each said that science communication would help save people in times of crisis, provide a means for scientists to talk directly to people, and get funding for scientific research. One participant could not provide an answer about the function of science communication (Table 4.2).

Regarding their perceived role in science communication, 12 participants indicated that they believed they needed to communicate directly to the public, whether through the Internet, on television, or on the radio. Five (5) participants believed that they needed to communicate with the lay public, but only as information providers or consultants that would check the work of science communicators before it was released in the popular press. Three (3) participants believed that scientists should be allowed to communicate directly to the public only if they were capable of talking to the lay public (Table 4.2).

When asked to define risk communication, 6 participants believed that risk communication was a way to explain risks to the lay public. Two (2) participants thought that risk communication was a way to explain why something was a risk by providing a context as to when such a risk should actually worry people. Two (2) other participants each defined risk communication as a proactive way to communicate risk to people in order to warn them about danger, and a way for scientists to explain risks to government officials. Ten (10) participants did not know what risk communication is or could not define it (Table 4.2).

When asked about their perceived function of risk communication, 8 participants thought that it was for the public to understand the risk of using or adopting different types of technology. Three (3) participants thought that risk communication was for people to know the truth about risks, while another 3 believed that risk communication is for people to know what to do and how to react in times of crisis. Two (2) participants thought that risk communication should not be done because it was too risky, and even unethical to carry out. Another 2 participants believed that risk communication was to prevent any panic in the lay public in times of crisis. Two (2) participants each believed that risk communication was a way for scientists to save people, and to get funding for more research. Another 2 participants did not know what risk communication was for (Table 4.2).

When asked about their perceived role in risk communication, 11 participants thought that they should communicate directly to the lay public, whether through television, radio, or the Internet. Five (5) other participants believed that they were meant to be providers of information only, but not direct communicators of risk. Three (3) participants believed that only scientists capable of interacting with the lay public should be allowed to communicate risk. One (1) participant believed that scientists should not communicate risk at all (Table 4.2).

What are the worldviews and cultures of the participating researchers?

In this portion of deductive analysis, the researcher read through the data and highlighted portions of participants' responses that addressed their worldviews and culture. These typologies were presented earlier in the Methods section of this document, and are detailed in Appendix G. When the data were coded using the typologies, the researcher summarized the ideas from the participants' responses under each typology. The researcher looked for overarching themes within the summaries of the typologies. These overarching themes were then used to recode the already marked data. The researcher then used these coded portions of the data to create generalizations to answer the research question and its sub-questions.

These generalizations are presented in list form in this section, and tabulated tallies of some responses will be provided where they are applicable. These generalizations will be supported by direct quotations from the data, as well as discussions of these quotations in context, in the next chapter.

What is the worldview of the participating researchers?

The participants in this phase of the study espoused a post-positivist worldview, but still believed in the ideals of positivism. This finding is a consolidation of the views of participants regarding the various aspects of worldview, including their ontological, epistemological, and methodological beliefs.

These views will be discussed in the next chapter and will be substantiated by direct quotations from the data.

The participants were also asked to define what a scientist or engineer was. Their responses are presented in Table 4.3.

Table 4.3:

Definitions of Scientist or Engineer According to Filipino Participants

Profession	**Definition**	**Frequency**
Scientist	Doing research in field and providing evidence	8
	Expand knowledge and do something practical for people	5
	Ask important questions	1
	Have a degree in science	1
	Produce and publish work in journals	1
Engineer	Do research to come up with something useful for people	3
	Work for public safety	1

Eight (8) participants believed that scientists carried out research in their fields and provided evidence for phenomena. Five (5) participants believed that scientists were there to expand knowledge and to do practical research that would benefit more people. One (1) participant believed that scientists asked important questions and found ways to answer these questions. One (1) participant believed that a degree in science was all that was needed to be considered a scientist. One (1) participant believed that scientists produced work and published them in scientific journals (Table 4.3).

Three (3) of the four engineers believed that an engineer was someone who carried out research in order to meet the practical needs of the lay public. One (1) engineer believed that engineers worked on projects that would ensure public safety (Table 4.3).

What is the culture of the researchers?

The generalizations presented in this section are a consolidation of the views of participants regarding the various aspects of the science culture. These views will be discussed in the next chapter and will be substantiated by direct quotations from the data.

1. The participants saw the following as the values of science: honesty, openness, passion, love for knowledge, mental capacity, and societal impact of one's work.

Of the 20 participants, 18 valued honesty, 14 valued the societal impact of one’s work, 7 valued the love for knowledge, 7 valued mental capacity, 6 valued passion in one’s work, and 4 valued openness. . The values are arranged as presented in the generalization because some of the values are related to each other, or were connected to each other by the participants themselves. They are discussed as arranged in the next chapter, and are supported by direct quotations from the data.

2. The perceived values of science give rise to the perceived norms of science: honesty gives rise to objectivity, openness to collaboration, passion to hard work and mentoring, love for knowledge to constant updating of one's knowledge base, mental capacity to creativity and systematic work, and societal impact to good research productivity and publishing.

The 20 participants mentioned various norms of science. Of the 20 participants, all 20 mentioned hard work, all 20 mentioned research productivity, 18 mentioned systematic work, 17 mentioned objectivity, 15 mentioned updating one's knowledge base, 14 mentioned publishing, 12 mentioned creativity, 10 mentioned collaboration, and 10 mentioned mentoring. The norms are arranged as presented in the generalization because some of the norms are related to each other, or were connected to each other by the participants themselves. They are discussed as arranged in the next chapter, and are supported by direct quotations from the data.

3. Science dictates that scientists should not overconclude or overinterpret their data; be dishonest; hide their work; be lazy; lose their objectivity; or copy other people's work. If the scientists broke the rules, science as a field would stop growing, and lives would be placed at risk.

The 20 participants discussed what was prohibited in science, as well as the consequences of breaking the rules. Of the 20 participants, 18 discussed laziness as prohibited in science, 18 discussed dishonesty, 7 discussed hiding the results of one's work, 5 discussed overconcluding or overinterpreting data, 5 discussed losing one's objectivity, and 4 discussed copying other people's work. According to 15 participants, breaking the rules would halt growth in science and engineering. According to 9 participants, lives would be at risk if researchers broke the rules. The prohibited activities and consequences are arranged as presented in the generalization because some of them are related to each other, or were connected to each other by the participants themselves. The prohibited activities and consequences will be discussed in the next chapter, and will be supported by direct quotations from the data.

4. The science that is taught in school is very different from how science is practiced.

This finding is a consolidation of the views of participants regarding their early socialization experiences in their research fields. These views will be discussed in the next chapter and will be substantiated by direct quotations from the data.

How does the surrounding culture of the researchers affect their work?

The findings in this section are broken down into themes that cover the researchers' views on their surrounding culture. Each generalization will be provided a tally of how many participants made such an assertion. These findings will be supported by direct quotations from the data and a discussion of the quotes in the next chapter.

1. Filipinos are often too sensitive and lack assertiveness.

This cultural trait was mentioned by 9 participants and will be discussed and supported by direct quotations from the data in the next chapter.

2. Politics plays a large role in who gets to do what science.

This cultural aspect was mentioned by 10 participants and will be discussed and supported by direct quotations from the data in the next chapter.

3. Filipinos are often reliant on Western science.

This cultural trait was mentioned by 5 participants and will be discussed and supported by direct quotations from the data in the next chapter.

4. Filipinos often have crab mentality.

This cultural trait was mentioned by 4 participants and will be discussed and supported by direct quotations from the data in the next chapter.

5. Filipinos lack commitment to long-term work.

This cultural trait was mentioned by 4 participants and will be discussed and supported by direct quotations from the data in the next chapter.

6. Lack of funding exacerbates the poor research and communication situation.

This finding was mentioned in various contexts by the participants, and is a consolidation of their views. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

7. Doctoral training abroad removes Filipino cultural elements that hamper scientific work and science communication

This finding was mentioned in various contexts by the participants, and is a consolidation of their views. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

8. The Filipino culture has elements that can encourage good scientific research.

Six (6) participants mentioned various cultural elements, and this finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

9. Religion has different effects on the researchers, scientific work, and science communication.

Of the twenty participants, 12 described themselves as being religious, while the rest either had no religious beliefs or were non-practicing Christians. Of the 12 who described themselves as being religious,6 participants believed their religious beliefs affected their scientific work. The details of this cultural aspect will be discussed and supported by direct quotations from the data in the next chapter.

What does it mean to be a civic researcher?

In this portion of deductive analysis, the researcher read through the data and highlighted portions relevant to the typologies of Trench's (2008) classification of science communication, Swidler's (1986) culture-as-toolbox model, and Lam's (2010) boundary-setting framework. These typologies were presented earlier in the Methods section of this document, and are detailed in Appendix G. When the data were completely coded using the typologies, the researcher summarized the ideas and concepts that were coded under each typology. The researcher looked for patterns, relationships, and themes within the summaries of the typologies. These overarching themes were then used to recode the already marked data. These overarching themes were then used to formulate generalizations, which were used to answer the research questions in this section of the dissertation.

What science communication model do the researchers follow?

The views of the scientists in this phase of the study are consistent with belief in the dissemination model of science communication. This finding is a consolidation of the views of participants regarding the various aspects of science communication, including their views on the nature of science, the nature of scientific knowledge, the role of scientists in communicating, the lay public, and the goals of science communication. These views will be discussed in the next chapter and will be substantiated by direct quotations from the data.

What is the culture of the civic researchers?

The findings in this section are broken down into themes that cover the researchers' views on the science communication culture. These findings will be supported by direct quotations from the data and a discussion of the quotes in the next chapter.

1. Today's science demands that scientists take on different duties outside the laboratory: they need to communicate to the public and collaborate with researchers from other fields.

This finding was mentioned in various contexts by the participants, and is a consolidation of their views regarding how the culture of science has changed. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

2. The way that science communication is conducted clashes with the traditions of science.

This finding was mentioned in various contexts by the participants, and is a consolidation of their views regarding the science communication culture. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

3. Science already provides scientists with some of the tools needed to cope with change, but scientists believe that they need more tools and resources to help them, such as social scientists, science communicators, and communication training.

This finding was mentioned in various contexts by the participants, and is a consolidation of their views regarding the tools researchers need to meet the requirements of the science communication culture. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

What boundaries do the scientists set between themselves and the lay public? Themselves and communicators?

The findings in this section are broken down into themes that cover the researchers' views on the boundaries between scientists and various players in science communication. These findings will be supported by direct quotations from the data and a discussion of the quotes in the next chapter.

1. The researchers are Communicating Hybrids when dealing with the public: they are aware of their social obligations to communicate but experience no role identity tension.

This finding was addressed in various contexts by the participants, and is a consolidation of their views regarding their obligations to the lay public. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

2. It is difficult to discern the boundaries that scientists set between themselves and knowledge brokers because they want to change knowledge brokers, or simply want to carry out science communication on their own.

This finding was addressed in various contexts by the participants, and is a consolidation of their views regarding the other players in science communication work. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

The participants were asked to provide their opinions on the social sciences and social scientists. The participants' responses do not total 20 because some participants sometimes provided more than one response. In total, 15 participants agreed that the social sciences could be considered sciences, and that the social scientists could also be considered scientists.

Their responses are summarized in Table 4.4.

Table 4.4:

Summary of Filipino Participants' Views on Social Sciences/Scientists

Question	Response	Qualifier	Frequency
Are the *social sciences* sciences?	Yes	None	5
	Yes	Help bench science	5
	Yes	As long as there are numbers/rules	4
	Yes	Uses the word "science"	2
	Yes	But data is different	1
	Depends	Needs rigor and facts	2
	Not Sure	Hard to study humans	2
	No	Does not use numbers	1
Are *social scientists* scientists?	Yes	They use scientific methods	4
	Yes	Need to use the scientific method	4
	Yes	Just work with different data, methods	4
	Yes	Contribute to understanding	1
	Depends	Need rigor, reproducibility	2
	Not sure	Approach is different	1
	Not sure	Need facts	1
	No	Do not use computational tools	1

Of the 15 participants who agreed that the social sciences were part of science, 5 gave an unqualified response, 5 believed that they contributed to the acceptability and impact of the bench sciences, 4 considered social sciences as sciences only if there were statistics and strict rules to govern research, and 1 believed that only the nature of the data set bench and social scientists apart. Two (2) participants considered only certain social sciences, such as demography, as science because they had statistical rigor and worked with facts. Two (2) participants were not sure because the social sciences studied humans, who were unpredictable. One (1) participant believed that because the social sciences did not use numerical methods, then they could not be considered science.

Of the 15 participants who believed that social scientists were also scientists, 4 believed that social scientists already used the scientific method by default, 4 believed that social scientists needed to learn how to use the scientific method before they could be considered scientific, 4 believed that social scientists simply worked with different data and methods, and 1 believed that social scientists contributed to science's general understanding of the world. Two (2) participants believed that if social scientists applied rigor to their methods and had reproducible data, then they could be considered scientists as well. Two (2) participants were not sure if social scientists could be considered scientists: one believed that the approach was different, and the other thought that social scientists needed more facts. One (1) participant thought that social scientists were not scientists because they did not use computational tools, numbers, or statistics.

These views and opinions will be discussed and direct quotations from the data will be provided to substantiate these claims in the next chapter.

Results of inductive analysis.

This section of the dissertation addresses the final research question: What other aspects of research, though not tackled by the frameworks, can be valuable for future research? In order to answer this question, the researcher conducted an inductive analysis of the data. Inductive analysis involved rereading the interview transcripts for data that had not been coded or did not fall into the conceptual frameworks used in deductive analysis. As the researcher read through these parts of the interview transcripts, she searched for frames of analysis: these were data that appeared significant, were repeated through the rest of the interviews, or presented intriguing avenues for future research. The researcher found that the researchers' critique of the social sciences, their discourse on their families, as well as their reactions to the interview were repeated through most of the interviews and were also interesting.

The researcher then searched for semantic relationships among these frames of analysis. This search yielded the following domains: characteristics of the social sciences, family influence on career, teacher influence on career, and positive reaction to interview. These domains were used to recode the interview data, and both confirming and disconfirming data were marked as part of the domain. Each domain was analyzed, and themes were searched for between and among the domains. There were no themes that were common to all the domains, but each domain was dominated by a major theme. These major themes are presented as generalizations in this subsection and will be substantiated by direct quotations from the data and a discussion of the quotations in the next chapter.

What other aspects of research, though not covered by the conceptual frameworks, can be valuable for future research?

The findings in this section are broken down into themes that cover the researchers' views on various aspects of their lives that were not addressed by the frameworks used in deductive analysis. These findings will be supported by direct quotations from the data and a discussion of the quotes in the next chapter.

The social sciences contribute to the knowledge base, but they must employ the rigor of the bench sciences before they can be considered scientific.

This finding was mentioned in various contexts by the participants, and is a consolidation of their views regarding the social sciences. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

Family and teachers, along with economics, play a great part in the choice of science career.

This finding was mentioned in various contexts by the participants, and is a consolidation of their early socialization experiences in research. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

The researchers' reactions to the interview process can also be attributed to the science culture.

This finding was mentioned in various contexts by the participants, and is a consolidation of their opinions of the interview process. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

The process of interviewing the researchers benefited them in various ways.

The participants were asked to comment on the interview process. They were asked what they thought about the interview, what questions they found difficult to answer, and what their overall reaction to the interview was. The participants also provided additional feedback side from the responses they gave to the questions. These responses are summarized in Table 4.5.

Table 4.5:

Summary of Filipino Participants' Feedback on Interview Process

Question	Response	Qualifier	Frequency
What did you think of the interview?	Interesting	None	4
	Fun/Enjoyable	None	4
	Not sure	None	4
	OK	None	2
	Good	Comprehensive	3
	Good	Learn something about myself	3
	Good	Talk about non-science things	1
	Good	Clarified philosophies	1
Did you find any of the questions difficult to answer?	None	None	7
	Culture	Hard to define	6
	Any indirect question	Vague	5
	Any definition question	Hard to define	1
	Objectivity	Have not thought about it	1
What is your overall reaction to the interview?	Good	None	11
	Made me think	None	5
	Not sure how interview will be analyzed	None	4
	None	None	1
Other Reactions/ Additions	Come back to help the Philippines	Need good science communication	3
	Good interview design	Comfortable, was able to confide	2
	Ask if scientists come from middle class	None	1
	Study Filipino-American scientists	None	1
	Have survey	None	1
	Want copy of document	None	1

The participants' responses do not total 20 because some participants sometimes provided more than one response. In general, 16 participants rated the interview favorably, while 4 others were not sure what to think because they wanted to see the data first. Of the 16, 8 participants gave no qualifiers for their responses, but said that they found the interview interesting, fun, or enjoyable. Two (2) did not qualify their response but simply said that the interview was "OK." Eight (2) said that the interview was good for various reasons: 3 thought it covered a lot of ground, 3 thought that they had learned something about themselves, 1 thought it was relaxing because it talked about non-science topics that could still be applied to the sciences, and 1 thought that it clarified philosophies. The 4 participants who were not sure about the interview wanted to know the objective of the data because they did not know where the questions were leading.

Seven (7) participants did not find any question difficult to answer. However, 6 participants thought it was difficult to answer questions on culture because they had not thought about their culture, and it was hard to define. Five (5) participants thought the indirect questions were hard to answer because they were vague. One (1) found it difficult to make any definitions whenever any question asked for them because definitions were difficult to make. One (1) found the question on objectivity difficult because the participant had never thought about the concept of objectivity.

Eleven (11) participants reported a generally good reaction to the interview, with no qualifiers. Five (5) participants thought that the questions were difficult overall, and that they were made to think about their practice. Four (4) participants asked the researcher how the interview would be analyzed because they did not know how statistics could be used to carry out analysis. One (1) participant did not express any overall reaction to the interview.

Three (3) participants wanted the researcher to return to the Philippines to help improve science communication. Two (2) participants complimented he researcher on her project and the interview design, and shared that they were able to confide in her. One (1) participant asked for a copy of the researcher's thesis.

The participants also made some recommendations for future research. One (1) recommended that a survey portion be made first before an interview was conducted. The participants also recommended research directions, including asking if scientists were all from the middle class, and if Filipino-American scientists were considerably different from Filipino or American scientists.

These findings will be discussed and direct quotations from the data will be provided to substantiate these claims in the next chapter.

Findings from the United States

This subsection presents findings from data gathered from participants based in Purdue University in the United States. This section is divided into three major portions: information on the participants, results of deductive analysis of the interviews and field notes, and results of inductive analysis of the interviews and field notes. The results of both deductive analysis and inductive analysis will be presented as generalizations that answer the research questions individually. These generalizations will be supported by quotes from the interviews and field notes, as well as a discussion of the quotes.

Basic information on participants.

Of the 1,018 potential participants, 188 were female and 830 were male. Three hundred and seventy-three (373) participants came from the College of Engineering. The rest of the participants were from the College of Agriculture, College of Science, Veterinary Medicine, and Pharmacy. In total, 55 potential participants were requested to participate in the study after three passes of systematic random sampling. Of these 55, 9 were female and 46 were male. Of these 55, 21 were from the engineering field, while the rest were from the bench sciences and mathematics. From the 55 potential participants, 20 ultimately agreed to participate in the research. This met the requirements of this research, which aimed to interview 20 participants. Of these 20 participants, 4 were women and 16 were men. Each participant was assigned a gender-appropriate pseudonym using names common to Americans: Anthony, Bethany, Christopher, David, Ernest, Fred, George, Harold, Irene, Jessica, Kevin, Larry, Michael, Nathaniel, Oliver, Patrick, Queenie, Robert, Steven, and Tim. Descriptive characteristics of U.S.-based participants are presented in Table 4.6.

The 20 participants were between 30 and 68 years of age. Sixteen (16) were bench scientists or mathematicians and 4 were engineers (Table 4.6). All of them worked full-time at Purdue except for one participant, Fred, who was an adjunct professor employed by a government agency.

Sixteen (16) of the participants were married, and two had been married twice. Two participants were divorced. The 2 remaining participants were single.

Table 4.6:

Descriptive Characteristics of U.S.-Based Participants

Pseudonym	Age	Gender	Field	Specialty	Ph.D. Origin	Marital Status
1. Arthur	48	Male	Natural Sciences	Genetics	U.S. Midwest	Married
2. Bethany	55	Female	Natural Sciences	Molecular Biology	U.S. East Coast	Married, 1 child
3. Christopher	43	Male	Natural Sciences	Entomology	U.S. Midwest	Single
4. David	38	Male	Mathematics	Theory	U.S. West Coast	Single
5. Ernest	54	Male	Natural Sciences	Genetics	U.S. Midwest	Married, 2 children
6. Fred	52	Male	Natural Sciences	Genetics	U.S. West Coast	Divorced
7. George	31	Male	Engineering	Chemical Engineering	U.S. Midwest	Married, 2 children
8. Harold	62	Male	Natural Sciences	Biophysics	U.S. East Coast	Married, 2 children
9. Irene	56	Female	Natural Sciences	Molecular Biology	U.S. East Coast	Married, 2 children
10. Jessica	50	Female	Natural Sciences	Veterinary	U.S. Midwest	Married
11. Kevin	51	Male	Natural Sciences	Entomology	U.S. Midwest	Married, 6 children
12. Larry	60	Male	Physical Sciences	Physics	U.S. East Coast	Married, 1 child
13. Michael	53	Male	Engineering	Mechanical Engineering	U.S. South	Married, 3 children
14. Nathaniel	59	Male	Natural Sciences	Ecology	U.S. Midwest	Divorced, 1 child
15. Oliver	68	Male	Physical Sciences	Physics	U.S. East Coast	Married, 3 children
16. Patrick	56	Male	Natural Sciences	Ecology/Chemistry	U.S. West Coast	Married, 6 children
17. Queenie	30	Female	Mathematics	Applied	U.S. South	Married
18. Robert	43	Male	Engineering	Applied Sciences	U.S. West Coast	Married, 1 child
19. Steven	31	Male	Engineering	Electrical/ Computer	U.S. South	Married, 4 children
20. Tim	62	Male	Natural Sciences	Biology	India	Married, 3 children

Fourteen (14) of the married and/or divorced participants had children, while 4 had none.

All but 1 of the participants reported receiving their doctoral degrees in various universities in the U.S. Four (4) participants reported receiving their degrees from universities on the West coast, 5 from universities on the East coast, 7 from universities in the Midwest, and 3 from universities in the South. Tim reported receiving his doctoral degree at a university in India.

Interviews with the participants ranged in duration from 48 minutes to 2 1/3 hours. All interviews were conducted in the participants' offices. All of the interviews were completed. None of the participants asked to go off the record with any of their responses. All participants spoke in English, so no translation was needed. The interviews were professionally transcribed; the researcher rechecked and made minor corrections to the transcriptions before analyzing the data.

In terms of data presentation, an ellipsis (…) is used to indicate that words were omitted for clarity. The designation *[sic]* is inserted where participants' unedited quotations are used that could contain grammatical or other structural errors.

Results of deductive analysis.

The Deductive Analysis subsection will provide answers to the research questions of this study by presenting generalizations derived from the patterns and themes in participants' responses to the interview questions. These generalizations will be supported by tallies of participant responses, where answers to questions can actually be tallied. These generalizations will be supported by a discussion and quotes from the data in the next chapter.

The last research question, however, which involves data not addressed by the conceptual frameworks used to guide this study, will be answered in the Inductive Analysis section.

How do the participating researchers define science communication?

To answer this research question, the researcher tallied participants' answers to the questions involving science and risk communication in the interview. These questions asked the participants for a definition of science communication, of risk communication, the aims of science and risk communication, and the role of scientists in science and risk communication. Some of the tallies for the various answers given total more than twenty, since some participants presented lengthier answers that contained more than one element in the total response pool. Responses are summarized in Table 4.7.

When asked to define science communication, 8 participants believed that it was a way to interpret research results to make them understandable to a general audience. Five (5) participants believed that science communication was about communicating scientific findings to different audiences, using audience-appropriate language. Three (3) participants believed that it was a way to explain to the general public why research was important and why it should be funded or supported. One (1) participant each believed in the following: science communication was about letting the audience know how science was being applied

Table 4.7:

Summary of Communication Definitions of U.S.-Based Participants

Concepts	**Science Communication**	**Risk Communication**
Definition	Interpret research results (8) Communicate to different audiences (5) Explain importance of research (3) Communicate applications of science (1) Field of study (1) Don't know (3)	Help people understand risk (2) Communicate risks, hazards, negative implications of work (2) A way for people to appreciate relative benefits and risks (1) Inform without risking science (1) Don't know (14)
Aim of Communication	Make people understand big questions of science (9) Educate people (7) Make people appreciate science (5) Allow public to talk and discuss research (2) Hold scientists accountable for findings (1) Simplify complexity of science (1) Increase funding (1) Make science relevant to non-scientists (1) Recruit people (1) Increase research impact (1)	Make people better informed about risk (6) Change behavior and help people make informed decisions (2) Minimize risks (1) Make people discuss risks (1) Avoid panic (1) Raise awareness about risks (1) Not sure or don't know (8)
Role of Researcher	Communicate directly (8) Involved in team (4) Only researchers with gift of communication should be allowed (3) Only researchers with communication training should be allowed (1) Be involved only if you want to (1) Requirement at all levels for engineers (1) Engineers should work with intermediaries (1)	Communicate directly (13) Limited involvement (6) Be involved only if you want to (1)

to different fields, and science communication was a field of study that looked at how scientists communicated with different audiences. Three (3) participants did not know what the phrase "science communication" meant (Table 4.7).

When asked about their perceived function of science communication, 9 participants thought that it was to simply make people understand research and the big questions in science. Seven (7) participants thought that science communication served an education function, so that people would know how to use science in making good decisions or changing their behavior. Five (5) participants thought that science communication was a tool to make people appreciate science and why it was important. Two (2) participants thought that science communication would allow the public to talk and discuss research in the same manner as scientists did. One (1) participant each believed that science communication would: hold scientists accountable for their findings, simplify the complexity of science, increase funding for science, make science relevant to non-scientists, recruit people into science, and allow research to make a larger impact (Table 4.7).

When asked about their perceived role in science communication, 8 participants believed that scientists should be directly involved. Of these 8 participants, 2 did not think that it should be a requirement for scientists, 1 believed that scientists should be even more involved than they currently were, 2 believed that scientists were already involved in communication by default because of their credentials and work in the laboratory, and 1 thought that scientists only needed training in communication but had all the other tools needed to communicate to the lay public. Four (4) participants thought that scientists should work with other professionals on teams in order to craft science communication messages, since scientists had the knowledge and expertise but not the communication means or training. According to these 4 participants, the job of the scientist was to look at condensed versions of their work to check that the information provided was correct. Three (3) participants believed that only researchers gifted with simplifying research should be allowed to communicate. One (1) participant believed that only researchers who were trained to communicate should be allowed to. One (1) participant believed that researchers did not have to be involved in communication unless they truly wanted to. One (1) engineer wanted communication to be a requirement at all levels, while another engineer thought that working with intermediaries, such as media experts, would be better (Table 4.7).

When asked to define risk communication, 14 participants said that they did not know what risk communication was about. Two (2) participants thought that it was for helping people to understand the risk of certain issues in science. Another 2 participants thought that risk communication involved communicating the hazards, risks, and negative implications of their work. One (1) participant each thought that risk communication was defined as: a way for people to have an appreciation of relative benefits and risks, and “informing without risking one's science” (Table 4.7).

When asked about their perceived function of risk communication, 6 participants thought that it was to make people better informed about risk, with “no frills” and “no nonsense”, so that people could correctly identify what was a risk. Two (2) participants thought that the purpose of risk communication was to change behavior and help people make informed decisions. One (1) participant each thought that risk communication was to minimize risk, make people discuss risk the way that scientists did, avoid panic, and raise awareness about risks. The remainder (8) of the participants was not sure or could not identify the function of risk communication (Table 4.7).

When asked about their perceived role in risk communication, 13 participants thought that scientists should be directly involved in risk communication. Of these 13 participants, 4 explained that scientists knew the facts and were involved in the work that calculated risks, 1 said that scientists needed to provide a basis for their claims, and 2 voiced that risk communication was difficult because the public did not understand statistics. Six (6) participants thought that researchers should be involved to a limited extent. Two (2) believed that scientists should be in charge of looking at condensed versions of reports so that they could make corrections. Two (2) engineers believed that engineers could be involved only if people needed answers to specific questions that only engineers could answer. One (1) participant believed that scientists should work only as consultants with the media, and another one said that only scientists with expertise in the risk should be involved. One (1) researcher believed that scientists did not need to be involved in risk communication unless they truly wanted to do so (Table 4.7).

What are the worldviews and cultures of the participating researchers?

In this portion of deductive analysis, the researcher read through the data and highlighted portions of participants' responses that addressed their worldviews and culture. These typologies were presented earlier in the Methods section of this document, and are detailed in Appendix G. When the data were coded using the typologies, the researcher summarized the ideas from the participants' responses under each typology. The researcher looked for overarching themes within the summaries of the typologies. These overarching themes were then used to recode the already marked data. The researcher then used these coded portions of the data to create generalizations to answer the research question and its sub-questions.

These generalizations are presented in list form in this section, and tabulated tallies of some responses will be provided where they are applicable. These generalizations will be supported by direct quotations from the data, as well as discussions of these quotations in context, in the next chapter.

What is the worldview of the participating researchers?

The participants in this phase of the study espoused a post-positivist worldview, except for two participants, who espoused a positivist worldview. This finding is a consolidation of the views of participants regarding the various aspects of worldview, including their ontological, epistemological, and methodological beliefs. These will be discussed in the next chapter and will be substantiated by direct quotations from the data.

The participants were also asked to define what a scientist or engineer was, depending on which field they were working in. Their responses are presented in Table 4.8. George and Robert held doctoral degrees in engineering fields, but decided to define what scientists were because they worked in the sciences.

Table 4.8:

Definitions of Scientist or Engineer According to U.S.-based Participants

Profession	Definition	Frequency
Scientist	Finds answers to important questions to push knowledge forward	9
	Asks questions and uses methodology to answer them	3
	Has training in science	2
	Has degree and credentials and applies method	1
	Discovers new knowledge	1
	Don't know/Too broad	2
Engineer	Has training and credentials	1
	Field is too broad/hard to define	1

Nine (9) participants believed that scientists looked for answers to important questions and used their answers in order to push knowledge forward. Three (3) participants believed that scientists were tasked with asking questions and then using a specific methodology in order to answer these questions. Two (2) participants believed that training in science was enough to be considered a scientist. One (1) participant believed that scientists needed to have a degree and credentials, but also needed to apply a specific method to answer questions. One (1) participant believed that scientists discovered new knowledge, and did not work on repeating experiments or confirming research done in the past. Two (2) participants thought that it was difficult to define what a scientist was because the field was too broad.

One (1) engineer believed that engineers had both training and credentials before they could be considered engineers. The other engineer believed that it was difficult to define who could be considered an engineer because the field was too broad, and that it was easier to define what a scientist was versus defining what an engineer was (Table 4.8).

What is the culture of the researchers?

The generalizations presented in this section are a consolidation of the views of participants regarding the various aspects of the science culture. These views will be discussed in the next chapter and will be substantiated by direct quotations from the data.

1. The epistemologies of science undergird its values and norms.

This generalization is the theme that covers the generalizations below. It will be supported with direct quotations from the data and a discussion of these quotations in the next chapter.

- The values of science include advancing knowledge and the scientific field, objectivity, ethics, having an impact on society, rigor and good experimental design, integrity and honesty, and passion for learning.

Of the 20 participants, 20 valued objectivity, 17 valued advancing knowledge and the field, 17 valued rigor and good experimental design, 15 valued integrity and honesty, 15 valued impact on society, 12 valued passion for learning, and 7 valued ethics. The values are arranged as presented in the generalization because some of the values are related to each other, or were connected to each other by the participants themselves. They are discussed as arranged in the next chapter, and are supported by direct quotations from the data.

- The epistemological beliefs and values of science give rise to its norms of: open-mindedness, critical thinking, admitting one's mistakes, careful and systematic work, asking questions and exploring, learning and establishing a firm knowledge base, truthful communication, working on high-impact research, disagreements amongst scientists, and mentoring.

The twenty participants mentioned various norms of science. Of the 20 participants, 18 mentioned careful and systematic work, 17 mentioned critical thinking, 12 mentioned asking questions and exploring, 12 mentioned learning and establishing a firm knowledge base, 11 mentioned open-mindedness, 10 mentioned working on high-impact research, 10 mentioned disagreements among scientists, 7 mentioned admitting one's mistakes, 7 mentioned truthful communication, and 6 mentioned mentoring. The norms are arranged as presented in the generalization because some of the norms are related to each other, or were connected to each other by the participants themselves. They are discussed as arranged in the next chapter, and are supported by direct quotations from the data.

2. Science dictates that scientists should not manipulate data, lose creativity and critical thinking, plagiarize, or sacrifice integrity for money. To do so would be to destroy one's career and reputation.

The 20 participants discussed practices prohibited in science, as well as the consequences of breaking the rules. Of the 20 participants, 15 discussed manipulating data as prohibited in science, 15 discussed losing creativity and critical thinking, 6 discussed sacrificing integrity for money, and 5 discussed plagiarism. According to all 20 participants, researchers' careers and reputations could be destroyed by breaking the rules. The prohibited activities and consequences are arranged as presented in the generalization because some of them are related to each other, or were connected to each other by the participants themselves. The prohibited activities and consequences will be discussed in the next chapter, and will be supported by direct quotations from the data.

3. Scientists do not always deal well with the world outside the laboratory. They are more introspective and observant, lack political savvy, and struggle to communicate well and relate well to non-scientists. In addition, the real world does not share the values of scientists.

This finding is a consolidation of the views of participants regarding their experiences with non-scientists and non-research work. These views will be discussed in the next chapter and will be substantiated by direct quotations from the data.

4. For participants, their research is a hobby, not a job.

This finding is a consolidation of the views of participants regarding the nature of their work as researchers. These views will be discussed in the next chapter and will be substantiated by direct quotations from the data.

5. The science that researchers learned in school is very different from how science is practiced.

This finding is a consolidation of the views of participants regarding their early socialization experiences in their research fields. These views will be discussed in the next chapter and will be substantiated by direct quotations from the data.

How does the surrounding culture of the researchers affect their work?

The findings in this section are broken down into themes that cover the researchers' views on their surrounding culture. Each generalization will be provided a tally of how many participants made such an assertion. These findings will be supported by direct quotations from the data and a discussion of the quotes in the next chapter.

1. Science may need resources, but funding pressures have forced some researchers to work based on project impact, disregard negative results, and compromise their integrity.

This cultural aspect was mentioned by 6 participants and will be discussed and supported by direct quotations from the data in the next chapter.

2. Politics can drive funding and set the research agenda, but it can also focus research so that research has impact.

This aspect of culture was mentioned by 7 participants and will be discussed and supported by direct quotations from the data in the next chapter.

3. American culture emphasizes creativity and recovery from failure, and these features are sometimes not found in other cultures.

This cultural trait was mentioned by 14 participants and will be discussed and supported by direct quotations from the data in the next chapter.

4. Mass media often misinterpret and misrepresent both science and the lay public, which leads to confusion and ignorance about scientific facts.

This cultural aspect was mentioned by 15 participants and will be discussed and supported by direct quotations from the data in the next chapter.

5. The public does not understand science and scientists because of poor media reporting.

This cultural aspect was mentioned by 12 participants and will be discussed and supported by direct quotations from the data in the next chapter.

6. Religion can inspire questions or make scientists avoid certain research problems, but it cannot guide scientific work and should not affect individual scientists.

Of the 20 participants, 4 described themselves as being religious, and of these 4, 2 believed their religious beliefs affected their scientific work. The details of this cultural aspect will be discussed and supported by direct quotations from the data in the next chapter.

What does it mean to be a civic researcher?

In this portion of deductive analysis, the researcher read through the data and highlighted portions relevant to the typologies of Trench's (2008) classification of science communication, Swidler's (1986) culture-as-toolbox model, and Lam's (2010) boundary-setting framework. These typologies were presented earlier in the Methods section of this document, and are detailed in Appendix G. When the data were coded using the typologies, the researcher summarized the ideas and concepts that were coded under each typology. The researcher looked for patterns, relationships, and themes within the summaries of the typologies. These overarching themes were then used to recode the already marked data. These overarching themes were then used to formulate generalizations, which were used to answer the research questions in this section of the dissertation.

What science communication model do the researchers follow?

The views of the scientists in this phase of the study are consistent with belief in the dissemination model of science communication. The views of the scientists in this phase of the study are consistent with belief in the dissemination model of science communication. This finding is a consolidation of the views of participants regarding the various aspects of science communication, including their views on the nature of science, the nature of scientific knowledge, the role of scientists in communicating, the lay public, and the goals of science communication. These views will be discussed in the next chapter and will be substantiated by direct quotations from the data.

What is the culture of the civic researchers?

The findings in this section are broken down into themes that cover the researchers' views on the science communication culture. These findings will be supported by direct quotations from the data and a discussion of the quotes in the next chapter.

1. In the past, scientists needed only to get published, secure grants, and carry out basic science to find out how things worked in the natural world.

This finding was mentioned in various contexts by the participants, and is a consolidation of their views regarding the differences between today's science and science in the past. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

2. Today, researchers need to communicate honestly in different ways to different audiences because they are the experts.

This finding was mentioned in various contexts by the participants, and is a consolidation of their views regarding how the science culture has changed. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

3. The epistemological beliefs of scientists provide the tools for scientists to communicate well, but they still need the following additional tools in order to succeed: communication training, various intermediaries such as media experts in the communication process, and a general, more complete understanding of how science is learned and communicated.

This finding was mentioned in various contexts by the participants, and is a consolidation of their views regarding the tools researchers need to meet the requirements of the science communication culture. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

4. The epistemological beliefs and culture of science clash with the culture of science communication.

This finding was mentioned in various contexts by the participants, and is a consolidation of their views regarding the science communication culture. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

What boundaries do the scientists set between themselves and the lay public? Themselves and communicators? Themselves and social scientists?

The findings in this section are broken down into themes that cover the researchers' views on the boundaries between scientists and various players in science communication. These findings will be supported by direct quotations from the data and a discussion of the quotes in the next chapter.

1. The researchers are Communicating Hybrids when dealing with the public: they are aware of their social obligations to communicate but experience no role identity tensions.

This finding was addressed in various contexts by the participants, and is a consolidation of their views regarding their obligations to the lay public. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

2. The researchers believed in keeping tight boundaries when working with the media.

This finding was addressed in various contexts by the participants, and is a consolidation of their views regarding their relationship with the mass media. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

3. It was difficult to discern the boundaries that researchers set between themselves and social scientists because they expressed no need to work with them.

This finding was addressed in various contexts by the participants, and is a consolidation of their views regarding social scientists. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

The participants were asked to provide their opinions of the social sciences and social scientists. Their esponses are summarized in Table 4.9.

Table 4.9:

Summary of U.S.-Based Participants' Views on Social Sciences/Scientists

Aspect	Response	Qualifier	Frequency
Are the *social sciences* sciences?	Yes	Adopt methods of natural science	6
	Yes	They find new knowledge	4
	Yes	Different data, interpretations	3
	Yes	They are governed by different laws	2
	Yes	Do what they can	1
	Depends	Not all are rigorous	2
	Not Sure	No opinion	1
	No	Subjective	1
Are *social scientists* scientists?	Yes	Already use scientific method	6
	Yes	Still need to use scientific method	5
	Yes	None	2
	Yes	Contribute to understanding	1
	Yes	They study something	1
	Yes	Work is important	1
	Not sure	No opinion	1
	Depends	They need rigor	2
	No	Subjective	1

In total, 16 participants agreed that the social sciences could be considered sciences, and that the social scientists could also be considered scientists. Of the 16 participants who believed that the social sciences could be considered sciences, 6 believed that the social sciences still needed to find ways to use the methods and principles of the natural sciences, 4 believed that the social sciences also found new knowledge and taught new things, 3 believed that the social sciences simply worked with different data and ways to interpret data, 2 believed that different laws governed the social sciences the way that laws governed the bench sciences, and 1 participant believed that the social sciences were no empirical, but they did what they could with what data they had. Two (2) participants thought that not all fields in the social sciences were rigorous, and those that employed rigor should be considered science. One (1) participant was not sure and had no opinion about the social sciences, while another participant believed that the social sciences were "a contradiction in terms" and therefore not to be considered sciences.

Of the 16 participants who believed that social scientists were scientists, 6 believed that 6 used the scientific method by default, 5 believed that social scientists needed to learn from the natural sciences and use the scientific method, 2 did not qualify their response, 1 believed that the social sciences contributed to understanding the world, another believed that simply studying something made it a science, and another believed that social science work produced important findings. One (1) participant was not sure and had no opinion about the social sciences. Two (2) participants wanted to see more rigor in the work that social scientists did, and would consider them scientists only when this condition was met. One (1) participant thought that social scientists were too subjective and were therefore not scientists.

These views and opinions will be discussed and direct quotations from the data will be provided to substantiate these claims in the next chapter.

Results of inductive analysis.

This section of the dissertation addresses the final research question: What other aspects of research, though not tackled by the frameworks, can be valuable for future research? In order to answer this question, the researcher conducted an inductive analysis of the data. Inductive analysis involved rereading the interview transcripts for data that had not been coded or did not fall into the conceptual and theoretical frameworks used in deductive analysis. As the researcher read through these parts of the interview transcripts, she searched for frames of analysis: these were data that appeared significant, were repeated through the rest of the interviews, or presented intriguing avenues for future research. The researcher found that the researchers' critique of the social sciences, their discourse on their families, as well as their reactions to the interview were repeated through most of the interviews and were also interesting.

The researcher then searched for semantic relationships among these frames of analysis. This search yielded the following domains: family influence on career, teacher influence on career, and positive reaction to interview. These domains were used to recode the interview data, and both confirming and disconfirming data were marked as part of the domain. Each domain was analyzed, and themes were searched for between and among the domains. There were no themes that were common to all the domains, but each domain was dominated by a major theme. These major themes are presented as generalizations in this subsection.

What other aspects of research, though not covered by the conceptual frameworks, can be valuable for future research?

The findings in this section are broken down into themes that cover the researchers' views on various aspects of their lives that were not addressed by the frameworks used in deductive analysis. These findings will be supported by direct quotations from the data and a discussion of the quotes in the next chapter.

School initiates interest in science.

This finding was mentioned in various contexts by the participants, and is a consolidation of their early socialization experiences in the sciences. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

Actually doing hands on work initiates and sustains scientific research.

This finding was mentioned in various contexts by the participants, and is a consolidation of their early socialization experiences and how they sustained research work. This finding will be supported by direct quotations from the data, and a discussion of the quotations, in the next chapter.

The researchers appreciated the interview process and intention.

The participants were asked to comment on the interview process. They were asked what they thought about the interview, what questions they found difficult to answer, and what their overall reaction to the interview was. The participants also provided additional feedback side from the responses they gave to the questions. These responses are summarized in Table 4.10.

Table 4.10:

Summary of U.S.-Based Participants' Feedback on Interview Process

Question	Response	Qualifier	Frequency
What did you think of the interview?	Well done	None	5
	Fun	None	4
	Good conversation	Intelligent, comfortable	4
	Challenging	Have not thought of issues	3
	Interesting	Teases out views	2
	Good	Vague	2
	Good	Like talking to a therapist	1
	Not sure	Too focused on science	1
	Not sure	Not sure of outcome	1
Did you find any of the questions difficult to answer?	None	None	8
	Culture	Hard to define	3
	Responsibilities	Not sure	3
	Communication	Not sure	2
	Objectivity	Have not thought of it	2
	Any question about scientists	Too broad	2
	Social sciences	No opinion	1
	Success of scientists	Too many	1
What is your overall reaction to the interview?	Good/Positive	None	11
	Interesting	None	5
	OK	None	2
	Challenging	None	1
	Fun	None	1
	None	None	1
Other Reactions/ Additions	Very comfortable	Easy to talk	4
	Interested in defense	Critical research area	4
	Send questions ahead of time	None	2
	Critical research area	Science being attacked	2
	Make questions more direct	None	2
	Good project	None	1
	Need science communication	None	1
	Ask: reward systems/salary	None	1
	Ask: male vs. females in science	None	1

In general, 18 participants rated the interview favorably. Two participants were not sure about the interview: 1 felt that it was too focused on science, and the other was not sure about the outcome of the interview and how it would be analyzed. Of the 18 participants who rated the interview favorably, 5 thought the interview was thorough and well done, and covered a good deal of ground. Four (4) participants thought that the interview was fun, 4 thought that they had a good conversation with the researcher that was both intelligent and comfortable. Three (3) participants thought the interview was good but challenging because they had not thought about the issues that had been raised. Two (2) participants found the interview interesting because it had teased out their views on research. Two (2) participants generally found the interview good but found some of the questions vague.

Eight (8) participants did not think that any of the questions were difficult to answer. Three (3) participants found it difficult to define culture because they had not thought about it before. Three (3) participants were not sure what the responsibilities of science and scientists were and therefore found the question difficult. Two (2) participants found the communication questions difficult because they were not sure about their answers. Two (2) participants had not thought about what objectivity truly meant, and they therefore found it difficult to define. Two (2) participants thought that any question about scientists was asking them to consolidate their views for a field that was too broad to define. One (1) participant had no opinion about the social sciences and therefore found the questions on social scientists and the social sciences difficult. One (1) participant thought that the questions on success were difficult because there were too many measures of success.

Nineteen (19) presented a generally positive reaction to the interview, with some saying that it was positive (11), interesting (5), OK (2), challenging (1), and fun (1). Only 1 participant did not express any overall reaction to the interview.

Four (4) participants found the interview comfortable and complimented the researcher for allowing them to talk. Four (4) participants asked to be invited to the researcher's dissertation defense because they found the area of science communication interesting and critical for science. Two (2) participants thought that the area of research was critical because science was being attacked in the press, and the researcher was therefore taking on a good project. One (1) participant simply said that the project was good, and another participant thought that science needed more communication work to be done. The participants also provided recommendations for future research. Two (2) participants wanted to receive questions ahead of time, and 2 others wanted the questions to be more direct. One participant each provided recommendations for future research questions: they wanted research on the reward systems and salaries of scientists, and the male and female ways of doing science.

These findings will be discussed and direct quotations from the data will be provided to substantiate these claims in the next chapter.

CHAPTER 5: DISCUSSION

The Discussion section of this dissertation is divided into three major subsections: The first subsection will discuss findings from the Philippine phase of the study, the second subsection will discuss findings from the United States phase of the study.

The first two subsections of the Discussion will first discuss the findings in the order presented in the Results chapter. However, in this chapter, the generalizations will be supported by direct quotes from the data and a discussion of the quotes in context. This will then be followed by a discussion of the data in the context of a combined framework of culture, worldviews, and communication models; and then a discussion of the findings in the context of a combined framework of culture-as-toolbox and boundary setting.

Finally, the third subsection will contain a general discussion of findings from both the Philippine and U.S. cultural contexts

Findings from the Philippines

In this portion of deductive analysis, the researcher read through the data and highlighted portions of participants' responses that addressed their worldviews and culture. These typologies were presented earlier in the Methods section of this document, and are detailed in Appendix G. When the data were coded using the typologies, the researcher summarized the ideas from the participants' responses under each typology. The researcher looked for overarching themes within the summaries of the typologies. These overarching themes were then used to recode the already marked data. The researcher then used these coded portions of the data to create generalizations to answer the research question and its sub-questions.

These generalizations are presented again this section, along with quotes from the data and discussions of these quotes in context.

Discussion of results from deductive analysis.

This subsection of the discussion will provide answers to the research questions of this study by presenting generalizations derived from the patterns and themes in participants' responses to the interview questions. These generalizations will be supported by a discussion and direct quotations from the data.

What are the worldviews and cultures of the participating researchers?

What is the worldview of the participating researchers?

All the participants in this phase of the study espoused a post-positivist worldview, but still believed in the ideals of positivism.

The participants believed that science was responsible for searching for truth, which is the aim of positivist science. However, the participants also acknowledged that knowledge could only be approximated, and knowledge could change depending on current tools and technology. Such a belief is concomitant with a post-positivist worldview. Lapid, a chemist, expounded on how the accuracy of knowledge was limited by current techniques:

> **Lapid:** ... you can't prove the mechanism … you can have the best explanation at that point ... at that point in time you just have so many tools and you have the best model. But then, *what*, ten years from now, someone's going to have better tools and then the mechanism, they'll come up with a better model. It doesn't mean that the model was wrong, it just wasn't the best at that point.

Alberto, a geologist, extended the reasoning further and conceived of knowledge as ever changing.

> **Alberto:** … well – well the thing is, you, you know, things are never cast in stone … things are changing. So what used to be correct yesterday, now, may not necessarily be correct tomorrow.

Some of the scientists also believed that scientific knowledge was cumulative, where scientists built their research on data obtained from previous experiments. Rita, a biochemist, explicitly called such work "data mining." Such reasoning assumes that the knowledge that has come before is accurate, or has been validated, and is therefore correct and can be built on. Julia, a biochemist, and Sarah, a marine biologist, reconciled these two views on the cumulative and changing natures of knowledge:

> **Julia:** You think of a problem, you know – you try to find out what is known about – about the organism, what is known – the reaction, what is known about the event, for example. And then you think of the techniques which are available, and you start asking a question, see if the techniques will – will be able – will be useful for the question that you originally asked, and then if the – if the – the - the available techniques and equipment are here, simply do the experiment. But it's – I think it's – the keyword I think is context – so you have – you have a scientific question, you put it in the context of what is known and what is available. And then you design activities around the availability of information as well as uh, resources.

> **Sarah:** Yeah – you follow the – the scientific method. You just – you observe, you try some sort of – see what is happening or what has been done. You sort out – you synthesize first and then you ask question. And then from your question, how do I solve this question? And then you try to see what has been done, and then make your own

> approach based on what has been done. Or innovate and try to see what can be done or what – what needs to be done. And then you come up with another result and then you give it to your peers and then this is what I've done, see if this is acceptable.

Sarah's response tends toward post-positivism, in that objectivity is achieved through peer review. Some of the participants also believed that the validity of knowledge depended on both the scientists and the methods that they used. Scientists such as Dina, Julia, Ofelia, Sarah, and Tanya believed that good data arose only from good and careful methodologies – which included reproducible methods that other scientists could use to confirm the validity of the data.

There were different interpretations of what steps and practices constituted the scientific method. Nearly all the scientists favored hypothesis-driven research and step-by-step procedures that were carefully documented. The positivist use of experimental controls, as well as the post-positivist validation of data by repeated experimentation, is present in Eva's explanation of the scientific method:

> **Eva:** And normally you – you do things with a certain hypothesis that is uh, you do the experiments with the proper controls – unbiased controls. And then you have an experimental data – but of course the – data is data…but of course it's also subject to experimentation, and uh it might also be dependent on sample size or on some other factors. But it is very, very important that you write your procedures very well and that they become reproduced by your other colleagues.

Rita, who was also taking courses in bioethics, cited how formulating a hypothesis set bench science apart from the social sciences:

> **Rita:** The [social science] method is not scientific – because we, we have a hypothesis. They – *it's like they're looking for a hypothesis. Is that how it's supposed to work?* (laughter)

Tanya believed that not all work could be driven by hypothesis. She had even asked for the hypothesis of the current research at the start of the interview. When the researcher informed her that there was none and explained why, she understood and voiced agreement with the explanation:

> **Tanya:** That's the creation of the hypothesis, and um, they have um, we were taught when we were young, first you have to have the hypothesis. So I asked you, what's your hypothesis? And of course you don't always have a hypothesis (laughter) so – um, uh, actually – uh - so now maybe the practice of science is no longer the scientific method.

Julia also mentioned how non-hypothesis-driven research might not be trustworthy, but later stated that scientific methods needed to be based on facts, and could differ depending on one's scientific field.

> **Julia:** I guess if it doesn't violate what has been so-called known as facts, then you can categorically call it scientific. If it's testable – if it's a hypothesis you can test and you can design an experiment to test it, then in my – in my book that's scientific. But that's because I'm an experimental scientist. If I were a theoretical scientist, there's no such thing as, you know, the scientific method that you can actually prove.

Julia's responses in general tended toward a positivist worldview, as she believed in a measurable reality that could be reported accurately. Later in the interview, however, she presented a post-positivist view of objectivity and acknowledged the personal limitations of individual scientists.

> **Julia:** Objectivity is theoretically always part of a scientist, but then when you form your hypothesis there's always bias, right? Because you cannot address all hypotheses at any point in time so depending on perhaps, what journals you've read, you're going to create a bias ... So there's always a bias somewhere along the way, but objectivity is useful when you're looking at data and you want to make your conclusion.

The scientists also believed in the use of appropriate experimental controls and a representative data set. Isabel and Tanya expounded on these views in their statements:

> **Isabel:** Um, gathering data while not being biased, that has representations of *what*, with a control, positive and negative, and then you have a hypothesis and you come up with a conclusion ...Yes, the whole population should be represented, not just the – because there is research where, the design is *what*, biased because they are envisioning what the results should be, so they con – they concentrate on a certain population.

> **Tanya:** So – what I'm saying is, some people will ask: Oh, do you need three trials? ... Why do you need three trials to say that something exists unless you know, you can't prove it, you can't show the, the primary data? ... One! You know, one test, or one run is enough. Ok – so it, it really depends. It depends on the field of research that you're in.

There were also particular ways of working that scientists favored. Many believed that numbers, statistics, and quantitative techniques allowed them to describe an objective reality. Carlos, an engineer; Eva, a molecular biologist; Glenda, an engineer; Marina, a marine biologist; Ofelia, a molecular biologist; Rita, and Sarah wanted to see numbers in scientific work. Tanya, a molecular biologist, associated quantitative methods with valid methods:

> **Tanya:** So – this is important, with a – with a method is uh, uh, reproducible, verifiable, quantitative, molecular, it is molecular, then it is – uh, should be quantitative, and if it is quantitative it is reproducible, and if it is reproducible ah, it it's uh verifiable

Lapid also associated numbers with a valid measure of reality:

> **Lapid:** Um, you know if it's too qualitative, you know anyone who can talk well basically wins an argument. So I wanted something more quantitative, so you could actually measure whether what you are doing is right or wrong.

Julia and Rita, both biochemists, had differing views on quantitative data. Julia voiced her reservations regarding quantitative data, while Rita believed that all data in science would eventually result in numbers:

Julia: If you're doing structural elucidations, that's all the data that you have, qualitative data, right? Spectra is qualitative data. Um, in fact I have – shall we say, I have more reservations for quantitative data as compared to qualitative data because in quantitative data you can – you can fudge it ar - a bit, I can change conditions ... but in qual – qualitative data, like, spectra, you really can't change where you're going to see the peak, so you're going to find the deltas, right? So – I think they're both acceptable, and if you really are mean, or and quite – quite creative – you can – you can fool around with both, but I think it's harder to fool around with qualitative data (laughter).

Rita: Yes – I rely on numbers actually, *right* – because if you go spectroscopy, you'll see numbers, too. If you go bioassay, it's numbers, too. Number of rights, or number of squirms, number of red – number of micronucleus, those are really numbers, too. And then – you do your isolations, you're still using numbers, 1st step of position, 1st step, weight of this, weight of this.

The biologist Quirino, like Julia, also had reservations about quantitative data. His statement mentioned how statistics did not equal reality when used in the social sciences.

Quirino: Uh, I talk to a lot of social scientists, they – they – they don't talk straight, they – they go around, around – so much talking. Number 2 is I think they're basically … statistics which I don't agree … mostly because it's just – statistics will just tell you the trends, it's not really – or the tendency – but not really the – the hard fact.

The participants also believed in repeated experimentation. That is, as long as results were confirmed and reproduced through different approaches and by different laboratories, then they were closer to the truth. Repeatability was equaled to validity, whether of methods or data. Such a view is consistent with post-positivism, which believes that triangulation can result in the best estimate of reality.

Marina used her field of research to explain how different approaches were required to confirm experimental findings:

> **Marina:** And then for instance you've already synthesized the sequence, *ah*, it doesn't have any activity, why did it turn out that way? Or is the activity different? So that means you sequenced something else, not that. So it's final proof that you are really right. And then this has to be supported by cDNA sequences. There, like that, so then – and then you have to do mass spec. It's like – there are a lot of methods in – in experiments – and you need those methods to be – they need to have consistency.

Nadia, a chemist, also believed in repeated experimentation and how reproducible methods were associated with trustworthy data.

> **Nadia:** Ok, if I do it now, if I do it tomorrow, whether that was done ... in the Philippines, will I be able to get the same results? If I'm – if I will not be able to get the same results, why? *So maybe the humidity is different, my month was different, it was windy, there* – I mean, that alone is a modification of the method, but at least, anyone would be able to reproduce it.

Carlos, an engineer, also believed that the results of a good research method approximated reality.

> **Carlos:** And then we want to uh, make a better method to bring it closer to reality. So you get a more accurate results, better design, uh, so the method would be scientific if it is as close as possible to uh, the natural, natural laws.

The scientists also believed in objectivity, but in varying degrees. Benigno, an engineer; Carlos, Julia, Lapid, Marina, Nadia, Ofelia, and Rita prescribed personal objectivity as a way to obtain reliable data. They believed that scientists were capable of examining results without being affected by anything except the need to find truth. Sarah, for instance, believed that complete objectivity was possible in laboratory work:

> **Sarah:** Objectivity is ... you forget that you are, that you are a Catholic, that you're a Filipino, you forget that you have a family … when you're doing it ... Maybe before I embark on something. I've chosen my path. This is what I'm going to do, and then when I'm there already I have to

be objective. Forget everything, forget about my – my family during the time I'm doing it, forget about the – forget – that I'm a Filipino.

The participants mentioned above, however, also believed in validating data through repeated methods by other researchers, a belief that is associated with post-positivism. However, not all the scientists believed that objectivity was possible in all fields of science. Flora and Eva, for instance, were open to "gut feel," but they both believed that gut feel needed to be borne out by experimental data. Hipolito said that he would rather admit his biases than claim complete objectivity. Kampo, a geneticist working for an international research institution, critiqued objectivity as the opposite of creativity:

Kampo: Like our chemistry back then, where we like, graph the cooling of – of – of water, and then when it's cooled, it will go down and go up again, there's a part there. If you ignore that, it should be straight, that's bad data, make it straight ... But there is actually supercooling along the way ... because if you're subjective, you have biases, you have favorites ... you have to be playful even in science because there are things there that happen – your favorites ... You need not to be objective, like what I'm telling others, all these decisions should not – need not to be logical.

Alberto presented another view of objectivity:

Alberto: As a matter of fact, uh, is it a requirement? That all scientists will know all the issues? Uh, what am I saying? Uh, this is a well (points to teacup). You know the story of the well, right? The one at the bottom – *the sky is beautiful, colored blue. The one in the middle, true, the sky is beautiful, and there are many green trees*. And the one at the top, *the sky is beautiful, the green trees are beautiful,* and the lake is really beautiful. All of them are correct, all of them are objective, but the frame of reference are *[sic]* totally different.

Alberto subscribes to a reality that is separate and measurable, and independent of those who observe it. However, the frames of reference of the observers limit how they measure and describe the reality. This difference in ability to describe objective, measurable reality is consistent with a post-positivist worldview.

Lapid presented both positivist and post-positivist views of objectivity.

> **Lapid:** Well of course, um, well that's what differentiates science from um, other areas. It's - well the objectivity comes in many forms. Ok, it's the objectivity defining the problem is one ... Of course objectivity is also in the methodology. And then later on, uh of course objectivity in, in choosing experiments that you could do, because there are many kinds of experiments, and many ways of doing an experiment, but you only choose three for various reasons, and you have to be somewhat objective in selecting those. And of course in analyzing your own data, you have to be objective. And then the last one is, in comparing your data and your results with someone else's. You have to be objective as well. So at each stage, objectivity is um, well in a way uh, you have to, um, be updated with what's going on – but then you have to stand behind what you actually assess.

Lapid stressed how scientists have to find the right answer, defend their findings, and provide evidence for their findings. His response provided a positivist definition of objectivity: self-accountability, dissociation of the scientist from social pressures, and a predictable world whose patterns can be discerned by careful measurement. He also stated that objectivity distinguishes scientists and scientific work from other activities, a view that is consistent with positivism. Later on, however, Lapid's views tended toward post-positivism:

> **Lapid**: ... actually ... there are many biases in medicine ... if you come from a certain worldview, when someone is sick, the research problem is to look for a drug. But from the other point of view, if someone is sick, then we'd say, do the research on why did he get sick? ... A lot of my friends are coming up with drugs for cancer, but they haven't answered the question: why are people having so much cancer? That's obviously environmental. But very few people are willing to look for those cancer-causing agents for such a lifestyle. Because lifestyle – obviously drug companies aren't so keen on lifestyle, wellness, especially – and so that's objectivity for you. But of course if you work for a drug company, your paradigm is a drug and you can be objective with that ... And – yeah – that's your bias.

In this sense, Lapid believes that different scientists will have their own biases that limit their work or define their objectivity. When these two statements are taken together, Lapid's view shows that he believes in two ways of ensuring objectivity: personal responsibility for one's data, and repetition of data by one's peers.

Like Lapid, Ofelia acknowledged that biases could affect scientific work, but still believed that individual scientists should be objective:

> **Ofelia:** … we all have our own acts – all the time we're always influenced by our own person, by our own upbringing etc. so I think it's an approximation. But as much as a person is able to, yes. A – uh – a scientist must be objective.

Only one scientist, Hipolito, believed that scientific work and thinking were not unique from everyday thinking and problem solving. The rest of the scientists, like Lapid, believed that their methodology and objectivity set them apart from society. For Alberto, Eva, Ofelia, Sarah, Marina, and Tanya, scientific thinking was not confined to the laboratory; scientific thinking was useful when they dealt with the outside world, as well.

> **Tanya:** The way you do your science is exactly the way you live your life. If your life is kind of sloppy then it's likely also that your science would be a bit sloppier. You know, if you have, uh high standards in your personal life, then you probably would also have high standards in science. But it's not always true, it's not always the case.

> **Ofelia:** The systematic meth – systematic method by which we approach problems is also something that is um, consistent with, with my way of thinking; and also the um, capacity to plan um towards a, a focused plan from an objective, to achieving that objective is – is something that I find is very good, in science as well as in everyday life … So one cannot be um compartmentalized with the four walls. And therefore, when we go outside the lab, you need not stop being a scientist. You just need to have other skills playing much more of uh, a

> role, and then you go back, and it has to be the cohesiveness of the person in order to bring it to life.
>
> **Glenda:** We're methodical. So if you have to – if you have to do something, there has to be step 1, step 2, step 3, step 4, and you have – you can't mix those up! We don't do it that way. At our homecoming, that's how we prepared ... and any event that we have in the college.

Sarah admitted her irritation when her scientific thinking was not shared by the lay public.

> **Sarah**: Because it's not scientific, it's not scientific or something. (laughter) I get irritated … I have to discipline myself … that not all people are like us. That they can be logical, they can be – they should be logical. They are objective. I should be more tolerant. *Me. I should discipline myself; as much as possible, uh, because that's the way things are. But sometimes, why shouldn't it be this way instead?* (laughter)

Nearly all the scientists acknowledged that science was influenced by politics, economics, and other societal forces. Nearly all the scientists believed that they were also tasked with improving the world through the use of scientific knowledge. Both these statements will be substantiated in the course of this document, since the data that supports them likewise fits into the other conceptual frameworks in this dissertation.

Many of the scientists believed in the power of science to control and improve nature, report the truth, and present the facts – all of which are marks of positivist thinking. On the other hand, the scientists also acknowledged that science could be influenced by societal forces, and that they needed to work on research topics that would benefit humanity.

To summarize this section of deductive analysis, the scientists espoused a post-positivist worldview, but believed in the ideals of positivism. In selecting what research to work on, defining objectivity, acknowledging the limitations of knowledge, and discussing valid scientific results, they tended toward post-positivism. In defining objectivity, framing their jobs as scientists, and describing the responsibilities of science, they tended toward positivism.

What is the culture of the researchers?

The participants were asked to characterize the science culture. While a few of them were able to answer the question directly, some of the participants struggled to articulate their views. For instance, Benigno, a civil engineer, did not have a ready answer for the engineering culture in the country.

> **Benigno:** The culture, it was a bit *what*, that, and – it's like I couldn't think of an example eh.
>
> **Interviewer:** That's really OK (laughter) you might just be a really diverse group.
>
> **Benigno:** Uh – uh – I really don't know. What I've noticed, OK, I already mentioned culture and the *what* – in civil engineering in particular, here in the Philippines....it's a bit weak, the promotion of a culture of research in civil engineering.
>
> Like Benigno, Rita was not sure how to answer the question.
>
> **Rita:** *Maybe that, like physics, they have messy hair, all curled up* (laughter). Culture – but the culture – for instance in physics, that's what scientists look like. I don't know, what is the culture of science? Maybe we're more *what*, more realistic? More – I don't know – although of course you can't say that honesty is part of the science culture, because it's culture, too, but – *what is this? What is – what science – what is really the culture of science?* ... (laughter) Although we all know each other….
>
> **Interviewer:** Is there a common bond among scientists, something that bonds -
>
> **Rita:** Maybe there is – there, low key – because we're all poor. Humble? ... What is our culture? Our beliefs? Maybe we're more straightforward; *we don't beat around the bush. I don't know.*

Despite their hesitation or outright difficulty in answering the direct question on culture, the scientists were still able to provide insight into their characteristics through the other interview questions. For instance, asking about the standards of success yielded responses on what the scientists valued in their practice. Asking about the scientists' responsibilities and jobs resulted in responses on the norms of science. In asking the scientists what scientists should not do or be, the researcher also received responses on the sanctions and punishments of the science culture. In inquiring about the scientists' experiences with science in school, the researcher uncovered how scientists were socialized into the culture of science. All these aspects of the perceived science culture will be presented in generalizations in this section. These generalizations are supported by direct quotes from the data, as well as a discussion of the quotes in context

1. The participants saw the following as the values of science: honesty, openness, passion, love for knowledge, mental capacity, and societal impact of one's work.

When asked about their measures of success in their fellow scientists, the participants were quick to cite the number of publications, recognition by peers, and even happy personal lives. When asked about how to achieve success in science, the participants also provided insight into the values of the scientific field. In this study, values were defined as aspects of their lives and career that the scientists held in importance. The answers that the participants gave were grouped into five major categories: honesty, openness, passion, mental capacity, and the societal impact of one's work.

Honesty was consistently mentioned as important in research. To engineers like Glenda and Carlos, and bench scientists like Julia and Kampo, honesty was part of the nature of their discipline.

> **Glenda:** Because in engineering if you are dishonest, a lot of people will die. If you're an electrical engineer, you do something about the design: change it or – try to save money – a lot of people would die if there's an electrical fire. Or, or if you're building a bridge, if you're a civil engineer, and you made some corrections in the computations. A lot of people will die. So I always tell my students: that is why, you know, engineers, we are an honest bunch of people because it's the only way that our profession would thrive ... Because for scientists, people perceive scientists and engineers to be truthful. Because it's the nature of our discipline. We say something, it is true. We – we – we – we are not – we do not know how to lie. It's not in our nature (laughter) to lie.

According to Julia and Kampo, scientists have to be honest because it is the nature of their field.

> **Julia:** As a field, you have to be reliable, you have to be honest with your data even if it's not the way you want it to be. Because that's – that's the whole foundation on it. If you cannot rely on your data set or somebody else's data set, then you have a house of cards and they will tumble down.

> **Kampo:** I think for a scientist, honesty is very important. Although for scientists, you can't – you have no option but to be honest. Because the truth will always out….

Benigno defined honesty in terms of sound research work and research integrity, which defined success in engineering:

> **Benigno:** He is respected by ... his colleagues ... in the sense that uh, the way he deals with the other professionals...they really know that he has integrity, *right ...* because we know ... that there are other professionals that were able to, let's say, do the project because of uh, like say, connections or something like that. But uh, there are really uh, successful ... civil or structural engineers that they were, they got the job because of work – their own – their product.

Another value that the scientists mentioned is openness. In this study, honesty was defined as the ability to tell the truth. Openness was the ability to share one's knowledge, not only with one's colleagues, but with the rest of humanity. Sarah and Pedro believed that scientists needed to allow their work to be criticized.

> **Sarah:** B – because you should be critical of yourself, of your work also, in the same way you should let other people criticize your work. Because it's a pool – it's a pool of expert minds working together in a problem developing things … a successful scientist has to reach a point wherein many or most of his work has gone through this peer evaluation of experts and then has already contributed significantly to the pool of knowledge where he is working.

> **Pedro:** I think the fundamental um principle behind the scientific matter, which also applies to uh, is that you should be willing to expose your work to scrutiny ... the key element that distinguishes scientific work is your willingness to expose yourself to scrutiny and I'm brave about it in my own work. In other words, I send my work out to be published in these journals, for all the world to see. If I make a mistake, millions of people will see the mistake.

Openness was also associated with the ability of researchers to work on a team, where scientists were expected to share knowledge with each other. Isabel mentioned how scientists needed to be transparent with their results. Nadia talked about how the culture of science was about sharing, which begets respect for other researchers' work.

> **Nadia:** So the culture of scientist, we share um, whether that would be the resources, or the data, and then the – that's it eh, uh – it could just be ideas, but we share it ... and then the respect – respect for – you already know someone is doing that, so don't – don't overlap or get what someone else is researching. Yes, so it's more sharing, and then respect for each one.

Passion was another value that was consistently mentioned in the interviews. For some of the participants, like Eva and Flora, passion was a requirement. For Ofelia, Lapid, and Alberto, passion meant that a person wanted to be in science and was willing to make sacrifices:

> **Ofelia:** Do you love science? Do you want to spend your time or a good majority of your time in doing science? Can you spend long hours in the – in the laboratory? ... when we talk about love with science … there's also a slight tingle of the passion.

Marina, who had already been recognized as a National Scientist in the Philippines, linked enjoyment and passion to working on science as a hobby.

> **Marina:** I always tell my students that in our time, when we started doing research, we just really enjoyed doing research. We didn't accept honoraria or anything. It wasn't the way things were back then (laughter). Where, you do research because you enjoy it, and it's like we consider ourselves lucky because it's like you're getting paid for a hobby, for something that you enjoy doing.

The participants also associated passion with a love for knowledge. Some of the participants believed that researchers needed to be curious and open to learning new things. They disclosed how they believed that knowledge was changing and expanding. One value that they held, therefore, was a commitment to keep learning.

> **Lapid:** ... a scientist always needs to be open to be able to learn, um, so what you know now is (inaudible) you can't say you're a scientist if you're – if you're satisfied with what you know now. So in that sense um, you have to be, you know, open to many new things

For some, the willingness to learn was also associated with the ability to realize the limitations of science. The participants valued an awareness of not claiming knowledge on everything, as Lapid mentioned earlier, and as Flora also stated in her own interview:

> **Flora:** ... despite everything that you know, you will realize that there is so much more that – to really know all about things. So continue applying diligence and humility. Ok – because when you think – when you think uh, you know so much, it can make you feel proud *right?* and with that pride you might say, 'I don't need to know anything else

> because I have – I – I – I already know so much, and I already know practically everything.’ You don't.

The willingness to learn was also associated with curiosity. Many of the scientists, such as Isabel, Sarah, and Julia, stressed that scientists always needed to keep asking questions. Nadia talked about the value of such a characteristic in students.

> **Nadia:** So what we tell the high school students is, don’t stop questioning, like, you ask, and ask, and ask – why this, why that? And we really tell the teachers, don’t be intimidated by students who ask a lot of questions because these are the students who are thinking. So always be curious, ask questions ... do not be disappointed....

In many of the interviews, the scientists named passion as a valuable trait alongside knowledge and logic. Tanya said that science required “more of a mental life.” Julia and Kampo added that creativity was also needed. Many of the participants talked about how scientists needed a good deal of knowledge to work in science.

> **Flora:** Research, mathematics, all the sciences, you really have to um familiarize yourselves, or yourself with um, the required content knowledge and procedural knowledge as well, ok?

> **Pedro:** So you – whatever field you happen to be in, one is you need the – the aptitude, and you won't be successful without the skills even if you were passionate about it.

> **Rita:** That, maybe expertise – mostly what people look for in science is your expertise eh ... Eh because you really need the aptitude, and not everybody can be scientists.

In addition to knowledge, participants also cited the need for scientists to be logical.

> **Marina:** ... but in science you can’t have just gut feeling. I mean you really have to think about it. Then very analytical – the analytical ability. And then science I think teaches you not to hurry up, I mean, not to be go with the flow. Wait, let’s think first. Things like that. And I

> think the scientific background in a way has uh has put us in the right track to how we deal with people. *Because sometimes, other people will see emotions immediately. So wait* (laughter) wait, let's think this over first.

Another theme that emerged from the data was how participants valued their obligations to serve society. Such a sentiment was pervasive, and scientists called upon it many different times, and to answer different questions. For one, Carlos measured a scientist's success through the impact that his or her research had made.

> **Carlos:** Yes – so how many people benefited from it? And how much business was generated out of the World Wide Web? So – that might be a measure, too – it's not so much how much wealth you amassed individually, but the effect of, uh, of what you did. You may not have gained from it individually, but if you want a quantifiable measure, I think that one is hard to argue against: Jobs generated and value generated.

Alberto talked about the importance of practical applications when he was asked to give a job description for scientists.

> **Alberto:** Job description is basically to expand knowledge. That's one. But at the same time making sure that this knowledge has a practical application. It may be now, or it may be in the future, but the thing is, that knowledge has to be translated into something practical.

Ofelia talked about the importance of useful research when asked about what data she considered scientific:

> **Ofelia:** Um, I'm very utilitarian. So I guess anything must have – or at least find the use for it, or have a purpose ... if it's going to be something that could provide greater peace of mind, it does not have to be tangible. It could be intangible. It could provide greater security. It could provide a resting place or uh or a – so the test – it has to have a reason, you really have to have a reason for being able to do something, or generating information. Otherwise, why generate information in the first place?

While she acknowledged that work had to have practical applications as well, Julia did not believe that she was required to tailor her research work to fit a practical application for the sake of politics.

> **Julia**: ... I learned that for a scientist to be worth his salt, here in the Philippines to be recognized, you also have to be politically correct, which is, a little bit sad, and disappointing. Um, you also have to learn how to package your ideas so that - it doesn't simply mean that – that – you're going to do research just because it's interesting, you also – have to say it's useful, and you have to have an empathy for the – always that phrase – for the poor – for the poor.

Many of the aforementioned values were addressed in a short statement by Tanya:

> **Tanya:** ... science is not for the … faint of heart or the weak of mind. It's true, right? ... I think we must have certain uh, um intelligence too, to become a scientist, otherwise, you're not made to be a scientist. So you must have the most basic attitude for science, for doing work that is organized, that is systematic, logical, and uh, thorough, and neat, and then aside from that add the element of uh diligence, perseverance, patience ... If you have to work with … researchers you must be uh easy to get along with. You cannot be moody, you cannot be uh, arrogant.

2. The perceived values of science give rise to the perceived norms of science: honesty gives rise to objectivity, openness to collaboration, passion to hard work and mentoring, love for knowledge to constant updating of one's knowledge base, mental capacity to creativity and systematic work, and societal impact to good research productivity and publishing.

In this research, norms are defined as the customary behavior of researchers and how they are expected to behave in science (Berk et al., 2000; Chalmers, 1999; Durlauf & Blume, 2011; Erickson, 2005; Gregory & Miller, 1998; Guba & Lincoln, 1994). Values refer to character traits, behavior, and concepts that participants hold in high regard (Berk et al., 2000; Chalmers, 1999; Erickson, 2005; Gregory & Miller, 1998; and Guba & Lincoln, 1994). Values dictate how scientists should behave, which, in turn, shapes the practices and norms of the science culture.

Honesty was framed as both a value and a norm. As a norm, honesty was defined in terms of citing references correctly. Such a sentiment was echoed by the many of the participants.

> **Eva:** So uh we should uh you should always be governed by the ethical principles of science by the fact that we should always never forget to cite people whose work we are basing our work on, and to acknowledge uh colleagues who have contributed to our work rather than taking as your own.

Honesty was also linked to objectivity, a trait which the scientists believed was not only important for scientific work, but a characteristic of scientists as well. For instance, Flora differentiated scientists from non-scientists.

> **Flora:** You're still a scientist if you really … apply objectivity.

Objectivity figured prominently in the data and was mentioned even when the scientists were not directly asked about it. Sarah, for instance, talked about objectivity when she was asked about how she was first interested in science.

> **Sarah:** That's why I saw the – the scientific method – the objectivity, the – the – the discipline in terms of thinking where you don't do things haphazardly eh, where anything goes. Ah! Because it's like, uh, uh, *pedestrian stories where* – I – I don't like it, it's nonsense for me. (laughter) Logical thinking. That's what I like.

Carlos likewise provided the perspective of engineers regarding the need for objectivity:

> **Carlos:** Um, I guess objectivity is uh, you know merciless ... about your appreciation of uh, phenomena, of the work that you're doing ... you cannot fudge if you're doing some engineering work because I guess, that's even more urgent of engineering ... Because uh, uh, you are

reminded that lives, property or even lives actually depend on what you're doing. You cannot fudge. So, always uh, you try to do things to the limit of what you know or of what the – you as a collective group will know, so that's why you have to keep yourselves updated eh. Uh, so that you can say that 'I tried to make this as safe as, uh, as possible.' So that leaves no error – no room for subjectivity, subjectivity in a way. Even when you're applying judgment, you're applying judgment, choosing something, but all of those would have been based on some objective, some objective uh, methods … coming up with alternative solutions to, to the problem.

Openness and sharing, both defined as values in the previous section, gave rise to the norms of collaboration and teamwork in science. Kampo and Tanya both believed that collaboration was something that scientists needed to adopt in the current research arena.

Kampo: ... especially in this age, you have to – to work with partners. You have to work together with others. Because the tendency of a scientist is to be isolated. That's already an old school – that's why they say if you – you want to travel fast, travel alone. If you want to travel far, travel together.

Tanya: ... it should be multidisciplinary, it should be multi-institutional, it should be um, with um, collaborators uh, based locally as well as uh, abroad. And there's always strength in numbers, there should be concerted factors, as in time, that's the only way for you to make an impact … to continue ... the research … in the past to the future.

This concept of collaboration and scientific universalism is already in the scientific literature. In Merton's (1942) norms, universalism defines science as a culture that transcends all other cultures.

The participants also consistently mentioned patience and hard work. According to the participants, patience and hard work naturally arose because the scientist simply enjoyed doing science.

Alberto: ... publishing a paper is not done during 8-5, especially with people like us. You, you have to do it past 5, or you even have to eat up during your weekends. So there are sacrifices involved. And this is something that, for scientists on the cutting edge, they understand.

Flora: ... you should be ready to devote time, energy, ok, to achieving your goals because things take time ok? ... you should really muster all the courage and the energy to uh, really apply yourself to what you want to do, ok? Because I believe that uh without effort and without uh giving yourself all the time*, right,* to really work on something you will not be able to ... achieve anything with what you do.

Sarah: Should be – should have the enthusiasm in the field. The interest in the field because if you don't have the interest, then you cannot – you cannot go ahead and then also – you don't have work hours. Re – you – it's timeless. If you need to stay here for, there, my students, they want to stay 24 hours, go, go.

Ofelia: Because you know, when you're talking about mentorship, when you're talking about collaboration, when you're talking about love of knowledge, it's a person's love for one's work that must be the underlying principle along this....

Like Ofelia, the scientists believed that mentoring was important, although not all of them had access to mentors as young researchers. Eva, Tanya, Nadia, Marina, and Kampo listed mentorship as one of the responsibilities of scientists. Ofelia went on to talk about mentoring and how it passed passion on to the next generation of scientists.

Ofelia: So, initially some, in particular the new ones, they might not have the passion. But one thing that the scientists, particularly the older ones have to try to give to the younger ones is the love for all this, the love for science, the love for information, the love for wanting to arrive at the truth and to give it to – to – to society. Because without having that passion, you will not be able to do your own work, you will not be able to mentor the younger ones because your younger ones will not look up to you because you don't have a passion. (laughter)

While passion was linked to one's love of knowledge, many of the participants also associated the love of knowledge to the scientific norm of updating oneself with knowledge. Participants such as Carlos, Dina, Isabel, Julia, Nadia, Ofelia, Sarah, Rita, and Tanya talked about how scientists needed to keep on asking questions, investigating, and updating themselves.

> **Carlos: ...** the way to do that would be uh, to … keep abreast, to know everything there is to know, to start with. And not, not even if you know everything there is to know, there are still other ingredients that would be required ... to me that's essential.
>
> **Dina:** To produce *what*, new knowledge, new products that will help improve lives. It's not just life, but health, general well-being. I think that's what it's all about, right? Because when you say science, it's really doing research, doing something more than what you have, modifying or changing, improving, things like that.
>
> **Julia:** ... you can't stop thinking what is a nice question to ask. Of course it may not be politically correct to ask that question. You have to be – you have to retain your curiosity about certain – certain things and how things work because nobody else is expected to do that except you.

Not all the scientists believed that a higher degree was a measure of how much scientists knew. However, the participants did not discount the importance of a higher degree, which they believed could prepare scientists for leadership roles and train scientists for further work.

> **Dina:** ... at first you see some people are material for Ph.D., some are not. And you see those in the MS, they do their job well but they are not very good at leadership roles.
>
> **Julia:** So it may be important, because a Ph.D. may show that you've been formally trained and that at least somebody who is supposedly in the know would have trained you adequately. So probably in terms of assuring that you have gone through the proper training – but a Ph.D. does not necessarily mean that you are going to be a scientist, because you can get a Ph.D. and be totally unproductive as a scientist.

The scientists also believed that participants were expected to be intelligent, and to use their knowledge to approach problem solving logically. This trait of scientists is also associated with the value of one's love for knowledge. For example, Hipolito and Julia characterized scientists as logical thinkers.

> **Hipolito**: ... the scientist ... has a systematic way of looking at uh certain phenomena, and he has a process of trying to verify things and also is able to present these findings ... it has to be – it has to stand the test of others who will look at it.

> **Julia:** Uh, we do have this um, peculiarity of – of – of thinking in – in discrete steps, right? So – step 1, step 2, step 3. We also have this inclination to do causal relationships, which is not usually in the common population, right? We also want to get more data every time we want to make a conjectural statement, right? So, what makes you say so – which is, you know, which is nice.

Lastly, because scientists valued their obligations to society, they were also expected to share their knowledge, communicate with different audiences, and also work on projects that had practical applications. For instance, Alberto and Ofelia believed that scientific work needed to have a direct impact in society.

> **Alberto:** ... first and foremost, they know their science and they conti – continue to blaze new grounds, and in the process they make sure that all their tacit knowledge are [*sic*] actually put into writing, be published. In the process they actually do a lot of extension services, making sure that what they're doing is actually applied on the ground.

> **Ofelia:** What for is that science, you are not creating an impact in that particular field? Whether it's in environmental science or forensic DNA technology, there must be some guidelines such that it would help even if – it would help society, even if you are no longer there. I mean, we are here a certain time, afterwards we are no longer the person who would be speaking about this particular advocacy. But your contribution must be explicitly formulated, written down, and used so that the impact, the change that you have done in your lifetime or in this number of years that you have been in the field, has to be felt not only now, but also in the future.

The participants believed that publishing allowed them to share data, which would therefore push the boundaries of knowledge and allow their field to grow.

> **Sarah:** And then you come up with another result and then you give it to your peers and then this is what I've done, see if this is acceptable. Because it's like that – you cannot have something and just put it there and keep it rot – rotting in your cabinet. You have to publish.

> **Rita:** Eh that's it, I want to publish (laughs) maybe to validate ... you've worked for years and you can't even publish it, there! There must be something wrong!

In summary, the participants operated under various norms which are, in turn, born of the values espoused by science. They are expected to be objective, to collaborate, to work hard, to mentor the next generation of scientists, to constantly update themselves with knowledge, to be creative, to be systematic, and to share the results of their work with both scientists and the lay public. The values that the participants mentioned also played a role in dictating what the participants believed were the sanctions and punishments of science.

3. Science dictates that scientists should not overconclude or overinterpret their data; be dishonest; hide their work; be lazy; lose their objectivity; or copy other people's work. If the scientists broke the rules, science as a field would stop growing, and lives would be placed at risk.

According to the participants in this study, honesty, openness, passion, love for knowledge, mental capacity, and societal impact of one's work were valued. When the participants were asked what scientists should avoid doing or being, they provided insight into what was prohibited in science. To summarize, dishonesty, secrecy, laxity, lack of objectivity, and copying other people's work were thought to be detrimental to their research and even place lives at risk. These traits and behaviors were also the opposite of what the scientists valued.

Dishonesty was mentioned earlier in the context of not properly citing one's sources, or not providing data to support one's claims. Dishonesty, as mentioned by

Carlos and Glenda, could lead to the death of people, especially in a field such as engineering.

Secrecy was also seen as detrimental to science. For instance, Isabel and Ofelia discussed how some laboratories refused to share their findings. According to Dina, secrecy also led to overlaps in scientific work:

> **Dina:** That's what's missing here in science in the country. There is so much duplication, overlap, everyone has their own agenda, they all each want to get the money, this person wants full control over the money. But if you look at it closely, there's just too many, you can come together.

Flora, Carlos, and Pedro discussed variations on the theme of laxity. Flora mentioned how laziness had no place in science. Carlos, in an earlier section of this document, talked about how not updating oneself with knowledge could "kill" the research field. Pedro complained that some researchers were confined to their fields and refused to learn new things. Dina, Sarah, Eva, and Kampo also talked about how laxity led to poor scientific work, whether in the methods used in the laboratory, or in interpreting data.

> **Dina:** So…that's it, *when the student just goes every which way in working*, there are people eh, who aren't really scientists – right – by, by definition, that's not a scientist anymore.
>
> **Sarah:** In thinking – you – you cannot be – how do you call it – the – where you work *haphazardly* – where, yes, that's ok, I already have to go, there is a term for that, in English, um, sloppy.
>
> **Eva:** And uh, whenever you make a conclusion, you should not overconclude. It should always be qualified with the methods and samples that you use.
>
> **Kampo:** If it has high error (laughter) it has a high CV. (laughter) Coefficient of variation or they call it overinterpretation.

As Dina already articulated, copying other people's work broke the rules of science. For Benigno, a civil engineer, copying American codes was also hampering research in the country.

> **Benigno:** For instance, it's like we just copy them ... although at the moment … it's only now, that we're already able to incorporate the, the local ... researches that enter – but still, it's still there, we're still dependent on foreign uh, outputs, *right* ... there are very few, really professional, professional civil engineers who are *really involved in research, right?*

The scientists did not explicitly mention any personal punishment besides not succeeding in science. The punishment of behaving badly, however, was far more pervasive. With secrecy and copied work, the research field would be at a standstill. And, more importantly, lack of objectivity and dishonesty placed lives at risk.

4. The science that is taught in school is very different from how science is practiced.

The scientists were asked about their experiences of science in school, with the aim of finding out more about the nature of science, as well as uncovering how the participants had been socialized into the field. The questions were also meant to inquire whether the culture of science in practice was different from the culture of science in the classroom.

For participants such as Marina and Isabel, school itself was "a game". For participants like Nadia and Kampo, science in school was like magic, where the students added chemicals to each other and then things happened.

> **Kampo:** Yeah – science – you know high school, the way it was for you, science is magic, right? If you're a scientist, magic – you mix

> chemicals, you drink, you're a child, stuff becomes big – your medicine, that's our magic, it's ... magic.

This perception of science changed slowly over time, as more training and more learning fostered a growing awareness of the norms, values, and sanctions of science. The participants developed a scientific worldview, and realized that the science that school had taught them was different from how science was practiced in the real world. Some of the scientists also mentioned that the science of school seemed to be absolute, where all the world's questions had been answered and where no additional work was needed.

> **Eva:** So in the beginning, science was a fascinating discipline, but I always thought uh, that there were so many scientists that you read in the books and there was nothing more to learn from uh, from science, I think, I uh – I - I – initially thought that they have [*sic*] answered all the questions.

As students, the participants were provided with knowledge that they simply needed to memorize. However, as time went on, and as they grew in their practice, participants such as Benigno, Carlos, Dina, Isabel, Julia, Kampo, Marina, Nadia, Ofelia, Sarah, and Tanya realized that they had not been taught skills such as working with a team or problem solving, and these were skills they developed in the workplace.

> **Benigno:** Of course, uh, ano, when you get to practice, you'll be – *you'll still be playing things by ear eh*. Because school is different, because in school, familiar pattern and problem solving, with teaching, with a teacher, like that. But in practice, some, some cases we don't know how to start (laughter) ... how do I start this? Because uh, you're dealing with ... actual problems eh ... So how ... are you going to divide the problems such that you can actually solve it using the tools that you have learned or practiced already, on the problems – that you will encounter in actual practice.

Another skill for which the scientists did not receive training was communicating with the public. According to Pedro, Tanya, and Carlos, the communication training that they had received, if any, was confined to writing for their fellow researchers.

> **Pedro:** ... unfortunately it requires an entirely different set of skills ... we're trained to be – to write things up for a specialist audience with the presumption the reader, uh, I mean could immediately look at the paper and already have some significant knowledge in the background. So you can sort of skip a lot of things and jump straight into: this is my contribution, uh following the things you already know.

> **Tanya:** And I say yeah, we need the communicators, and there are many examples of – scientists, by their nature, they're not good writers. Or they only write uh, in a scientific way, or they're trained to write in a uh straightforward way.

> **Carlos:** So we have people like those – but the engineers don't really train for that. Not really trained for that ... So – they even say that an attribute of an engineer would be to – now, in international practice and in international standards, uh, the outcomes of education, aside from, aside from uh being aware of environmental and social issues, you have to communicate – to communicate well orally and written form in the English language ... And I think just by putting that it's already a recognition of – you have to be – to consciously move toward that direction. Be good communicators.

The participants also discussed learning eventually that their work needed to benefit the public. According to some of the scientists, they had not been impressed with their societal obligations early on. For instance, Glenda and Carlos, both engineers, were part of programs that aimed to teach "soft skills" to the new generation of engineers.

> **Glenda:** ... we have started what we call Value Formation for Students. It's uh, kinda soft um, for example we have a group of faculty members called Valuers; their objective is just to put up programs that will foster values of two things only: nationalism and *compassion*. And then even our student organizations today uh, we have changed the,

> the game so to speak. Before, oh, about 30% of our students are members of orgs. But we've learned that the values that they will learn they will not get it from the classroom.
>
> **Carlos:** It wasn't like that back then – it's not impressed upon you. Maybe you learn it as a value, but it's now conscious in the curriculum, and uh, uh, in fact, in international practice, they, they also look for that now. That engineers that are produced are, know that there are other forces out there, not just engineering.

In addition to learning about how science functioned in society, the participants also learned that science was all about hard work.

> **Kampo:** But now if you be a scientist, it's really hard work. Small difference but it's a lot of hard work. You could progress slowly, you can't see immediately what's happening in science because science is hard work.
>
> **Quirino:** Uh – basically from elementary, it's basically textbook. And very simple, it teaches you ideas and – you get this impression that it is easy, but actually, in real terms, it's not. You need patience, a lot of patience, and a lot of observation, repetitions, um you need a lot of what – um looking backwards, at what you have done, reflecting. And then also going forward, uh I think it's very difficult uh especially that I have experienced that one when I do a dissertation. Because it's not the experimental part uh which I had a hard time, it was the interpretation of the data.

Further training in science also showed the participants that science was not absolute. For instance, Eva and Dina learned that there were disagreements on how to interpret data, and there were many questions still left unanswered by science.

> **Eva:** And then I realized that there were really a lot of questions and those that we reach at the basic level are still – very ... much ... not pursued or not known – or unanswered.
>
> **Dina:** Because it's like here, it's already known. Eh but when I – when I did – when I did my MS, I took my Ph.D., it changed. There are – this apparently is how you arrive at this knowledge. And then that – these things may or may not work, or what you find may not necessarily be what others will find.

Some of the participants also talked about how school science did not allow them to see how research could be applied to the real world.

> **Carlos:** ... if you have uh, professors who've been exposed to how it is outside, they would have actually put more meaning into, into the subject matter. Because it would be very, very theoretical but sometimes now looking back at it, like, if I were to teach it now, and I do teach it sometimes … to teach something, and show something about the real world. You know, the, the application.

Some of the participants claimed that they had changed their worldviews as they spent more time in science. To Sarah, science began by receiving knowledge, which she believed led to a love for learning more.

> **Sarah:** It's entirely different because being a scientist, when you practice the – it is different when you are – were trying to learn science in school, in grade school. Because you are given the knowledge already. It's like candy ... but how to make that candy ... the chemistry of the candy ... it's hard to just give it at that level, OK? So the love – the love to know and to know more and discover should be developed at that stage.

As the love of knowledge was developed, the participants learned about the methods of science, and how these methods could be used for scientific investigation. To Lapid, Ofelia, Pedro, and Carlos, science had become a way of thinking as well as a way of life.

> **Lapid:** I mean, you know, what they teach in high school, that there's a scientific method where you have a hypothesis, that stepwise, you know – it's only for high school teaching. In fact in scientific work there's a lot of lateral thinking as well.

> **Ofelia:** ... what I find in the science is actually very much skill-based. Once you know how to do or how to get the information, then you are able to do – to do any topic that you're required. Because you already know how to get... how to approach problems. It's not so much memorizing all the different things because there's so much information. But it's how to approach a problem.

> **Pedro:** Fundamental thing back then of course, especially in grade school, is that science is about accumulating knowledge, which is

> already present. And then – in high school it was a bit more methodology ... And then I learned the link between the math and the science which – at a younger age was largely qualitative. I learned that in high school. At college it was more like polishing, you can find applications....
>
> **Carlos:** So you have to grow old a little bit, uh, to know the entire context of uh, of, uh, of the knowledge that you have. So, that's it, so – right now – and then, uh, so it's just not knowledge that would be important because in engineering, you have to apply some decision-making, is important. Some of it, you can go and use the numbers, and it – you get the answer – but that's it, there are problems without – like design problems, they don't really have a single solution. And then, so comes the part about judgment, that's something maybe that you cannot learn or that cannot be taught in school.

As Carlos already mentioned, and as some of the scientists also said in their own interviews, increased training allowed them to see where their own knowledge fit. For Glenda, the realization made her merge two of her favorite topics in her master's thesis: music and engineering.

> **Glenda:** And then I said, wow, there's a connection to music! ... So I learned that there is a connection between art and engineering. And to me it – it was a journey getting here, now, I have collaborations with the College of Music, the College of Arts and Letters, because I understand these things are connected. But growing up, engineering, I thought it was just math.

For Hipolito, his experiences in science led to an appreciation for even esoteric projects that could move the field forward. Flora's response was similar, in that her experiences in mathematics allowed her to appreciate abstractions. Lapid reported that he appreciated how his research fit into the field after he had been published.

> **Hipolito**: It changed in terms of, maybe, uh, the appreciation of science for what it is ... maybe sometimes in the past, I would think that ... you should not be doing some esoteric things. Um, but once you are able to appreciate the broader scheme of things, you don't necessarily expect that everyone will be doing more towards applying

science ... because I think, you know, each has their own role – each science – uh person, whether an enthusiast or whatever, they have their own uh, role in the grand scheme of things, if there is a grand scheme of things.

Flora: ... I realized that uh for one to profit from a study of mathematics, one must be able to deal with so many abstractions, for which, uh one should have the capacity to think logically, OK? ... But um – earlier on, at lower levels of maturity, one would insist on the relevance of something that is taught you in the classroom, OK? Why am I – why am I being taught this, what good will it do me? ... But later on – later on as you mature, you are able to think of the ideas detached from the reality ... So that must be the time when I really, uh, enjoyed ... my study of math. At least you think of how the ideas relate, connect with another ... And so it gives you some unifying wholeness, whereas before they were really disparate areas of uh, knowledge. So now you are able to see how one connects with the others.

Lapid: You focus on one or two things. So in that sense, it's not so much the appreciation – well, of course, you have this notion that what you are doing is somehow important but you don't really get to pause and appreciate the big picture of this. You have to graduate and then get published – so you're focused on the output. It's only actually when you're done with – with that that you can - you can sort of look at other interests that um – you have the opportunity to take a second or third look, and then usually appreciation will grow. So usually I – it's not a linear process as I said, it's continuously appreciating science.

How does the surrounding culture of the researchers affect their work?

The participants were asked to talk about the Filipino culture and how it affected their work. There was a variety of responses to the question, and the participants mentioned cultural elements that both hampered and encouraged scientific work and science communication. Their responses will be presented in this section under various generalizations that were generated from the data, along with representative quotes and a discussion of the quotes.

Some of the participants believed that there were Filipino habits that could hamper scientific work and science communication. For instance, Sarah believed that the Filipino culture and Filipino mass media did not enhance scientific work. Marina and Benigno did not see a national culture of science and engineering, respectively.

> **Sarah:** Actually there's nothing in the Filipino culture that enhances … *Look at the television shows … the media. There, it's with the media that I'm most irritated.*

> **Marina:** It's like this … we don't have a national culture of science. It's not like in England, where … science is a big tradition. Right? The discoveries, the discoveries. They're traditionally good in molecular cloning – and in – microbiology, the traditional molecular biology – *so things like that. Nothing has come from here yet*

Like Sarah and Marina, Tanya voiced how the science culture was not strong in the Philippines. Her claim was based on different elements of the Filipino culture:

> **Tanya:** It's not very strong – culture in our country. And it's a function of … our training or the education of our … youth, and the strong religious beliefs, uh and uh with the ethnic beliefs of our people, so it's tied up closely with our – our culture and traditions … this current government – past ones did not have the political will to uh, uh support science, to put science in priority, then through the years uh um our education in, in mathematics and science and … the pursuit of knowledge uh has not been very strong.

These cultural habits will be examined in detail in the following subsections.

1. Filipinos are often too sensitive and lack assertiveness

Carlos, Dina, Glenda, Hipolito, Isabel, Lapid, Marina, Pedro, Sarah, and Tanya talked about how Filipinos were often very sensitive to criticism, and how they often took things personally. This made it difficult for them to break into and work in science, where criticism is open, and often harsh. The participants also talked about how Filipinos were not assertive, which often led them not to ask questions or question their fellow scientists.

The lack of assertiveness began in school, where students were expected to ask questions.

> **Carlos:** When I was studying in uh, the U.S., right, the professor asks 'Any questions?' Filipinos would be shy. Would not raise his hand to ask a question…They really want to speak up, but they're thinking that other people will think that they don't know anything! (laughter) … The Americans, they keep on raising their hands, they don't care, right? That's one – that's one of the first things that I realized (laughter).

Glenda was already aware of this disadvantage, and she had trained her students to be more assertive, and to question even her judgment.

> **Glenda:** If my student would tell me, 'Ma'am, that method is wrong,' and then if you ask the student to explain why, then that's ok. We are not like that in the Filipino culture … Right, like, where you're shy, or you're afraid of hurting someone, making someone mad.

This sensitivity, coupled with a lack of assertiveness, often shocked Filipino graduate students when they went to international conferences, as Hipolito related.

> **Hipolito:** … The graduate students … they might be a bit shocked when [we're] at an international conference because a lot of the Westerners are very blunt … like, that one time, 'Before, I thought you were…the cardinal of bullshit. Now I think I'm convinced you're the pope.' (laughter) Things like that … we worry a bit about what I say to you, *something like that*.

Glenda's and Hipolito's explanations of the lack of assertiveness are echoed through most of the interviews: Filipinos take a very personal approach to work, and they believe that everyone else has a personal connection to their work. Therefore, Filipinos will not criticize someone's work because they do not want to hurt that person; conversely, they do not want to be criticized because they have a personal attachment to their work.

Carlos elaborated on how such an attitude played out in the workplace.

> **Carlos:** … and when you argue, arguing with the boss nothing personal, on a technical matter, the Filipinos may have problems with that – with, you know, telling the boss, 'I don't agree with that.' But you know, thinking uh, he's in the Philippines, it doesn't work that way. That it works differently in other cultures. So, in fact, if you don't argue your side, some people in other cultures will think that you're not thinking.

Carlos related a similar story at a university in which he worked, and how his own cultural biases made him realize how different scientists were.

> **Carlos:** … you don't argue when we need to on technical matters … personal things that are not really personal. Right? … So when I was working in [University in the U.S.] I had a coworker then … it was all technical ha: 'I think we should do it this way, I think we should do it that way.' They went home, they were friends, and they rode the bus together (laughter). I thought, '*This crazy man* is going to get fired!' And they don't – it's nothing personal. So there's something in the culture maybe that gets in the way sometimes of things.

Marina and Pedro also discussed how sensitivity to criticism could impede a person's progress in his or her career.

> **Marina:** … the ability to uh accept criticisms, although that's so difficult for the Filipino culture … that's why a lot of people don't publish their work … when they get bad reviews, they don't want to continue. They become static, their work becomes stale, they don't want to show anyone their work.

> **Pedro:** If you send out a paper there, you're basically exposing yourself to criticism and … a lot of people are afraid of that … I sort of had the chance to … learn to take these comments in stride, but, if you're a young guy or a young lady, and your first paper which you've worked for … comes back rejected with all these nasty criticism, that could change your mind about your career. It could, conceivably. So I think that might stand in the way … I think Westerners are much more thick-skinned about these things.

In Isabel's experience, researchers in the Philippines would often consider a person's personality first before deciding to work with them.

> **Isabel:** … before they collaborate with you, they *check* your background first, *or stuff like that* (laughs). Compared – compared with the scientists outside the country, they ask what your expertise

> is, right? It's like – in the method, their orientation, here, is toward results. That's how I see it, because of the things I've experienced here, they'll – they'd rather have … 'Never mind, it's like, let's not do this because I'm not sure about – about that person.'

Isabel also linked the focus on personality to gossip, which she was also familiar with.

> **Isabel:** Office intrigues, of course, that doesn't disappear, we still have that. Um, they won't let you join a project even if um, *you have something to contribute, because – um, that's it,* personality.

2. Politics plays a large role in who gets to do what science

Alberto, Benigno, Dina, Glenda, Julia, Kampo, Lapid, Marina, Ofelia, and Tanya also discussed the role of politics and political maneuvers in moving and shaping scientific work. Alberto, in particular, noted how politics played heavily into who received funding. While Alberto was understanding of the politics of science and advocated for policies to guide scientists, Lapid and Nadia criticized Philippine politics.

> **Lapid:** I mean, politics here is … such that … none of the congressmen know any science.

> **Nadia:** Because … our politicians, uh, only a few of them understand science.

Glenda summarized her frustrations by providing the term locally used to describe political maneuvering.

> **Glenda:** You need a *padrino* and you need an outsider, who will tell them, this is how it is.

The *padrino* system is rampant in Philippine politics (Gripaldo, 2009). A *padrino* is anyone who is considered powerful and influential, and who is often from outside the country (Gripaldo, 2009). In Glenda's experience, she needed a *padrino* to convince government officials to fund academe-industry linkages. Without the *padrino,* Glenda claimed, the government would not have funded her at all.

The politics of science in the Philippines, however, also involves one's academic pedigree, according to participants. For instance, Lapid knew how government agencies were staffed with graduates of the University of the Philippines, the premiere state university.

> **Lapid:** … yeah, basically, the majority people rule. So um, well, in this case, if you look at the Department of Science and Technology … the people who run it, etc. I would say 80% of them would come from the University of the Philippines … Well, part of it - part of it is um just human nature. But then part of it is politics because then it's like an echo, you know an echo chamber. When you say one thing, then it echoes on the other side.

Some of the participants related their experiences in working with funding or government agencies, and how they needed connections in order to get their project funded. Benigno already provided an example earlier, of how civil engineers often worked on projects because of their connections, not because of their expertise. Politics could also play a role in dictating what kinds of research projects could be funded, and for how long.

> **Julia:** … if you cannot point to a particular utilization of your science, in the next five years or so, the likelihood that you get funding is nil … if you can package the research in terms of, uh, shall we say, rapid gratification in the short term, five, ten years – uh - ten years is actually far off – five years because then the lifespan of a president is six years – right? So they change policy every time we have a new president – so that's basically true, because they have to point out to a particular output eh. So who cares if you know the mechanism of cancer, unless you couch that as a research that will lead to the diagnosis of cancer, if you cannot look at it the mechanism per se. You will never get money for that, unless of course you're well connected politically.

Julia's statement is based on the politics of Philippine science at several levels. First, because presidents in the Philippines are in office for a maximum of six years, and with no chance for reelection, funding policies are good only for the same amount of time. Therefore, research has to be truncated to fit the six-year window. Second, unless researchers have political connections, or, as Glenda said, a *padrino,* their research focus will have to be changed.

3. Filipinos are often reliant on Western science

The Philippines lived under Spanish rule for over 300 years, under American rule for nearly 50 years, and under Japanese rule for around 5 years, before finally achieving complete independence after World War II (Caoili, 1986). The conquests of the Philippines are often blamed for the colonial mentality that pervades and negatively affects various aspects of Filipino life (Gripaldo, 2009).

Benigno, Flora, Julia, Kampo and Rita discussed how this colonial mentality played a role in science. For instance, Flora talked about how Western mathematics often made Filipinos think that they had no native mathematics to be proud of. Rita talked about how students wanted to graduate from schools in the United States because a graduate degree from abroad was prized in the Philippines. Kampo, who worked at an international research institution in the Philippines, talked about how Filipinos discriminated against their own countrymen.

> **Kampo:** You could fight with them scientifically, you could argue with them ... because for example in this community … even your fellow Filipinos, they look at Filipinos differently. Filipinos are kind to the whites - and we host different kinds of – Indians, Americans, all these British, French … if this [Westerner] talks … then they have more confidence in that person … that won't disappear eh. We are still in the colonial mentality….

Kampo went on to talk about how he was challenged to prove his worth. Nevertheless, he recognized how Filipinos tended to look up to Westerners.

> **Kampo:** That's why – you have to be way above them before they can see – that you're all equal together eh … So that's the culture that I see. We tend to – Filipinos – we tend to see ourselves lower than our counterparts.

To Julia, colonial mentality also translated into faith in imported protocols – a measure that had to be taken especially since funds are low.

> **Julia:** Here … we'd rather look at the materials that came from abroad and assume that it is actually uh, portable, the data will be portable, and then you simply do it the way they do. Ah, that's – that's - that's a harsh reality because of the shortage of funds.

Many laboratory protocols, however, are not easily translated to Philippine weather, which is humid and warm for nearly the entire year. However, according to many of the participants, because it appears that the West has a good grasp of what protocols work, many scientists adopt these protocols immediately – and often without question.

4. Filipinos often have crab mentality

Crab mentality can be described as people behaving like crabs in a basket. Crabs in a basket tend to pull each other down, and crabs that try to escape are pulled back into the pile by their companions. In social terms, this translates to people pulling each other down, whether through insults, gossip, or backbiting, so that society, as a whole, does not progress. Isabel, Marina, Ofelia, and Quirino discussed the various forms of crab mentality in the Philippines and how this orientation was impeding research progress.

Marina talked about power-grabbing in other laboratories, which she believed did not happen in her own laboratory. Quirino talked about how gossiping actually went against looking for the facts. Ofelia called on the scientific value of openness as she talked about the unhealthy competition amongst laboratories, which effectively put other laboratories down.

> **Ofelia**: … I've encountered situations where people are too much into competing against each other in order to become a better lab … I mean, there's healthy competition, but at the same time, with the limited amount of money, can we not work together, such that we arrive at the – at the bigger, uh, we – we go for bigger goals?

Like Ofelia, Isabel talked about openness in the form of transparency of results and compared the scientists in the Philippines to those who were abroad.

> **Isabel:** … you need transparency of results. Because, um, if you compare the scientists here and those who are abroad, right, it seems that here … they aren't that transparent with results, they're not that open to um, collaboration … they think about – the outcome immediately, the results immediately….

5. Filipinos lack commitment to long-term work

The *ningas cogon* mentality is another cultural trait that participants spoke of in the interviews. Cogon grass burns brightly when set on fire, but this brightness quickly disappears. The *ningas cogon* mentality denotes short-term commitment to work: people will burn brightly and contribute everything that they can in the beginning, but the work slows to a stop as people lose energy (Gripaldo, 2009). Lapid, Ofelia, Pedro, and Tanya talked about how the lack of commitment to long-term work also stood in the way of scientific research. For Pedro, the mentality was manifest even in graduate school, where students chose the easy route so that they could finish their work immediately and then get a degree. Hence, there were more master's students and fewer doctoral students.

> **Pedro:** Master's – we don't have that many Ph.D. students … one of things about the Philippines, a lot of people say, 'I want a Ph.D.' But when it gets down to the business end of things, for some reason, or for various reasons, they sort of get lost … Now, in the Philippines, I think master's is much easier because you're a student – and a student normally looks at a two-year horizon … So let's say, the average, one year, one and a half years to complete the master's thesis. Other than that, of course, the work tends to be much simpler than full Ph.D. works. So the, not so much the talent issue that comes along, but I think some of the um, cultural attitudes come into play.

Lapid mentioned how the lack of commitment to long-term work was evident in the transition between a Ph.D. and an actual science career. For Lapid, a Ph.D. often meant that someone who had worked hard in graduate school was no longer as productive after graduating.

> **Lapid:** It's … how long you can sustain that hard work. Some people will say that they can work very hard, but that's only for the three years that they're doing their Ph.D. After that, they don't work as hard anymore. So I think it's the state of the hard work, which is really if you can extend it year after year.

Ofelia offered examples of how the mentality extended to the workplace. In her experience, projects, once conceived, could not even begin when people knew that it was time to do work.

> **Ofelia:** … many times, people have idea … but when one starts asking, 'How will we do *it*?' people disappear … because it's time to work, ok? Let's start working, how will we do? There, everyone disappears.

Tanya discussed progress in scientific research: She connected her views with a lack of collaboration, which, together with the *ningas cogon* mentality, pushed science to stagnation.

> **Tanya:** … I believe that uh, um, in a country like ours, um, the reason we have not progressed in science is because scientific efforts cannot be – cannot be sustained, they are not continued over a long period of time. Every scientist just tries to work uh, by himself and mainly on his own, and does not have uh, a longer term kind of game.

6. Lack of funding exacerbates the poor research and communication situation

The participants in this study mentioned funding issues at one time or another, but always in the spirit of funding inhibiting the progress of science. They all agreed that they would have to live in an ideal world in order to get funding for all the things that they were interested in. At the moment, they had to be resigned to the fact that there were few funds available, and research had to be tailored to fit the demands of funding agencies.

Some of the participants, however, had already tried convincing government officials to put money in all kinds of research. Glenda talked about her argument with a high-ranking government official.

> **Glenda:** … he keeps saying that … these are the only tracks that we will fund. I said: You know, there are two types of researchers. One researcher, whatever fits into the available funding, that researcher will propose for it. That researcher will really get funds. That's one type. There is the other type, the one that you keep on giving money to. Sooner or later, he will come up with a fantastic idea that will innovate everything. It will change history. I said: We're only there in the first type. We are ignoring the second type. I said: We need to find mechanisms for those. So me, I believe that both types should be funded. But given the situation in our country, where we have limited funds, we are forced to just fund the first type.

Like Glenda, Pedro had also criticized the funding system.

> **Pedro:** Some of the science is only in the applied end of the spectrum. In other words you're putting in money in technologies which are on the cusp of being perfected, therefore that extra bit of money is what turns it into commercial work. Nevertheless you know, your problem

is that if you were to be competitive enough, work which is on the cusp of being perfected or commercialized is going to be the same anywhere in the world. In other words, it's very difficult for the Philippines to, say, invest money in biotechnology, and be assured that the discovery will be made here and not in the United States.

Pedro also proposed changes to the funding system.

Pedro: The other extreme of course is … science driven by curiosity… that basically is driven by intellectual curiosity, which is of course defined by the individual researcher … which are riskier but which um which tend to be more unique. In other words if what the Philippines was looking for was to run this on innovation which is not made anywhere else in the world, that has to be part of the picture. Because if you're trying to perfect hybrid vehicles already, there's people all over the Philippines who are trying to do work on hybrid vehicles and so forth – how are you going to match the investments being done on – by General Motors, or – not them anymore, but let's say, Toyota and Honda? There's no way we're going to match that. They definitely have every conceivable advantage. So I think it's essential basically, especially when we have little money to begin with.

Nadia also proposed her own solution to the funding problem, which she believed other countries already had.

Nadia: In other countries they can use things immediately because there’s a very, very strong link between industry and the academe … but we lack here the support of industry. We're trying to … but they still can’t see the role of the university or research in an academic institution that – that can help in their concerns in industry.

The participants shared their experiences in dealing with funding issues, whether they had to plan their work around limited funds, or change their research questions altogether. For instance, Quirino had to shift careers early on so that he could receive funding.

Quirino: When I came back for seaweeds … I started with … structures of uh, small molecules, biological activities. I applied for a grant but I was not able to get it. So I just stopped with seaweed because that's where the funding is. Um, otherwise I would have gone to isolation of molecules, and doing the biochemistry part.

Lapid also talked about the two-pronged problem of funding: research topic bias and research group bias.

> **Lapid:** Well for one thing you can only get funding if you apply it to certain problems so – so it's not free. There's also a bias toward certain groups. They get funding more easily than others. Access – access to funding is not easy.

Julia also tackled how packaging one's proposal meant keeping one's true aims secret.

> **Julia:** … you have to learn how to package your proposal, so you can promise for example that there is a needed cure for cancer, but then you can say that is the first few steps anyway – but you don't say that in your proposal.

Julia explained this need later on as she talked about what funding agencies tended to look for when assessing research proposals: They wanted product-oriented research. In Julia's case, knowing the mechanism of insect resistance should have led to better insecticides. The funding agency, however, was looking for better insecticides without the long years of work in elucidating the mechanism itself.

> **Julia:** They wanted to look at new insecticides rather than elucidating resistance mechanisms and find out where they act on. In – in a Third World country, mechanisms are not very much of a priority, it's usually how do you solve it, how you solve it, more than why is it there, when – when you know why it is there, then you start designing a strategy to combat it.

According to Kampo, the need for funding was affecting networking among scientists.

> **Kampo:** Our culture is … where's the funding? That's the sad reality. Where – where can I link, where can I use a laboratory? Like that – we are dependent on – that's our culture. We're always – if there's a scientist like that, whom we meet, it's also an opportunity, to link to them, because we have the opportunity.

Despite the preoccupation with funding, many of the participants still believed that they were objective. That is, they might have tailored their work to fit the needs of the funding agency, but they would still interpret their results objectively because science called for it. Ofelia couched this claim in terms of the surrounding culture and the ideals of science:

> **Ofelia:** However, the expectation, ideally, would be that scientists are not political, are not influenced by people – you are influenced by your goal, which is to arrive at the truth, as close to the truth as you can, which is what I define objectivity. So you are an objective scientist. However, I understand that in order to do so, you might need to find your way from A to B but you had to pass through X, Y, and Z to get to B. Because if you don't do that, then you won't get the funding to be, to do your research project. You will not be able to meet the people that you need to meet in order to get the project done. Nobody will listen to you. To me, ok, so you – you – you might be going through different institutes, or different legislators of whatever poli -political party, ok, that's fine with me.

7. Doctoral training abroad removes Filipino cultural elements that hamper scientific work and science communication

Fourteen (14) of the 20 participants received their doctoral degrees outside the Philippines, and some of them claimed that interacting with scholars from other countries provided a different perspective of research. For instance, Carlos talked earlier about how working in a multicultural environment made him more aware of the elements of his culture that contributed to poor practices in science. Dina and Ofelia believed they learned to be better mentors and leaders because of their exposure to doctoral studies abroad. Glenda had already imparted the objectivity and open criticism of science to her own students, which she believed had been instilled by her doctoral training abroad.

> **Glenda:** You know being trained as a Ph.D., being a researcher, they've been erased eh. In the past … Filipinos are shy … the type where they're afraid to ask questions because they're afraid that people will think that they're stupid. That's been erased eh. And then the being frank about, you know, your research sucks … that's been erased eh. Even my students behave that way. *If they listen to their colleagues, and then the colleagues flounder, they say so.*

Isabel discussed how her training abroad had made her more aware of what was wrong with the Philippine research culture:

> **Isabel:** … when I was exposed to um, people abroad, ah, we can still work without this kind of attitude … younger scientists here in the Philippines who won't be like that anymore. Or if they act like that, there will only be a few of them (laughs), and it won't be as bad as it was before.

8. The Filipino culture has elements that can encourage good scientific research

While many of the participants concentrated on how the Filipino culture was hindering scientific progress, some of them identified a positive side of the Filipino culture. In talking about culture, they provided a balanced vision of how Filipino culture was both hindering and encouraging for scientists.

While some scientists believed that funding encouraged secrecy and duplication, Julia believed that lack of funds also brought out resourcefulness in Filipino scientists. Researchers in the country were forced to learn more about adjunct scientific fields to make up for the lack of experts in the research arena, and were therefore, in her words, "better rounded."

> **Julia:** … sometimes you are better rounded than some of the specialists abroad. But – sometimes it amazes them that you can retain so much information simply because you've been forced to … I think a Filipino scientist, given - given the disadvantages that we have in here, are more adaptable into changing their major field of specialization than the Americans. Like, if for example, I get – uh,

> somebody with in the United States, I – I pick out that person and throw him in the Philippines to write grants, and, and get funded, let's say, to shift from working with insects and go work with fungi, we'll have a difficult time with him, but we can do it, simply by extending the information, the basic information that we know. There – so – if you check the people I used to work with, you still find them in insecticide resistance or with insect biochemistry, none would have gone to another field.

Julia also elaborated on how her generation of graduate students was resourceful when there were no funds available to do research. She related this to her ability to make her experiments less expensive.

> **Julia:** When we graduated, we were very creative in making things work, in making do. We had to make do with a lot of things eh. I can – I can dissect an experiment that will probably cost the Americans something like $150,000. I can do that for around $30,000. Yeah – that's because I knew the principles, and I can dissect it to steps that will be discrete so that I can – I can stop here, because I will run out of money and ask for more money. In America, you ask for the entire thing, you get a kit, and it's non-adaptable, right? If – if we do the science here, I won't let you do that, I won't let you buy a kit. You make it from scratch, so if – if you run out of one reagent, you can use whatever is here.

Filipino resourcefulness was also mentioned by other scientists, such as Rita and Kampo. Julia also went on to defend Filipino scientists, who in her opinion differed from foreign scientists only because they had less money to work with.

> **Julia: ...** I think there's basically no difference … in terms of the way we do science, it's just the way that – it's just the quantity of funding that we get. And so sometimes we do it in a very convoluted way mainly because you have been forced to change your methodology so much … it looks as if … it's quite laborious to come up with the same question.

Nadia also discussed the good traits of Filipinos in general, and Filipino scientists in particular. She talked about how her experiences as a scientist in Japan allowed her to compare the two research cultures, and see how Filipino cultural traits actually aided her.

> **Nadia:** I spent almost three months also in Japan, and I – I pitied them, because it's like, I ride the – the train, you know, and I was – I was of course, observant … I said, it's like their eyes are blank – nothing against the Japanese, but you know, they were like robots … There wasn't any – any emotion – and then our train, you see, they call it the orange line, and they say that psychologically, the orange line – orange color is what magnetizes people. That train was always caught in traffic because a lot of people would jump and commit suicide … I said: It's like … to them … without work, life is useless.

Nadia went on to talk about how the Filipino culture was different from Japan, and referred to specific traits.

> **Nadia:** … the results aren't good even if you're in the lab until dawn, it's like, let's just do this, it's really perseverance. It – it helped a lot. And then the close-knit family, that's very, very important … It's like … I saw the importance of … laugh at life … laugh at the adversities … that you encounter. The Japanese there *said to me*: '… You bring life.' They say that when they see me in the corridor, it seems like I always have joy … Very, very important: family, our resiliency, ability to laugh at our own mistakes … I think that is important, and then our faith.

Eva, like Nadia, had been trained in Japan. Her cultural comparisons, however, focused on how the two different cultures regarded and treated women.

> **Eva**: We have a lot of career women in the Philippines who can go to the upper levels of um, academia as well as corporate – um but I did not see this very well in … the culture where I pursued my graduate school. I had classmates who were female Japanese who were very smart but did not go beyond MS. They did not even pursue grad school … because uh, the stigma of going to grad school and being a spinster was just so great. And it's … very sad.
>
> She then brought the discussion to the Philippine research arena.
>
> **Eva:** … In the Philippines, we are, we are females so when we want to be treated like females, we behave like females. But if we want to be treated like equals, we behave as if we were genderless. So it's uh – it's the best of both worlds. (laughter) So in the Philippines you can have females who are on the top of the ladder, who are professors in the university without the fear of … sexual discrimination, gender

> discrimination … You can be whatever you want to be. If you're female, it's OK – this is the best place. So – in many cases in the foreign countries, um, it's a little bit difficult for a working mother to survive. In the Philippines there's a lot of support systems *[sic]*. Of course it's still difficult to nurture a family if you're a female, and to pursue a scientific – an um, academic life. But it has never been a deterrent.

Eva is a participant who is married with two young children, but who has been working in academia for over two decades. Glenda, a single woman, provided information on why Filipina women could advance freely in their careers.

> **Glenda:** I think our religion affects – I think it's one of the reasons why there are a lot of women in science and engineering…In fact when I went to uh Japan to speak to engineers, women engineers, I learned that only 10% of their … engineering students are women. And then uh we're at 47% here. I have learned by talking to … those coming from different countries. India and the Philippines have a high percentage of females in engineering. Our conclusion at that time, I don't know, we didn't have a lot of – it wasn't scientific (laughter) our conclusion was that, in a country *where a female acts as the leader*, like Mama Mary for us, and Shiva for them, there is a high percentage of engineering, of women in engineering.

Gender discrimination, to Glenda, at least, was an unknown term until she began doctoral studies in the U.S.

> **Glenda:** That's why – all of us, our Marian prayers are strong and all that? I think it's because of that … first time I ever encountered the term discrimination against women was when I did my Ph.D. in the U.S.. All my life, growing up, I never felt discriminated….

9. Religion has different effects on the researchers, scientific work, and science communication

Of the twenty participants, 12 described themselves as religious, while the rest either had no religious beliefs or described themselves as non-practicing Christians. The participants also reported varying degrees of how religion played into their research, or had affected them at different points in their lives.

Most of the participants, whether religious or not, explicitly stated that religion and faith fell outside the realm of science. Some of the participants did not mention religion earlier in the interview. When asked why they had not mentioned it, most of them said that they believed that religion was a personal choice, and that it had little to do with their work.

> **Tanya:** Religion is not science – myth, superstition, anecdotes, not science. Um, anything to do with uh faith, I think…it's not derogatory, it's just not in the realm of science. Supernatural is not in the realm of science.

To Eva, an assistant professor at a non-sectarian university, working in a religious university also meant that a researcher could not study any topic that he or she wanted.

> **Eva:** If you're talking about dogmatic or religious universities with a particular train of thought and views about certain things uh, I think in that particular case the scientists might be curtailed from pursuing their work – or just choose something safe. But as far as the University of the Philippines is concerned, and I think that is, uh, the beauty of being in the state university is that you can do the science you want to pursue.

The participants mentioned a variety of ways that religion could affect them indirectly. For instance, Pedro, an atheist, was aware of how religion often interfered with social issues such as overpopulation – and consequently, how it hampered the growth of a science culture in the lay public.

> **Pedro:** … there's no arguing that we have only so much space available … and considering you need land to grow food, and whatever else. There are some instances wherein there are clashes with – with religion, there are clashes between religion and science and there might be, to some extent, what gets in the way uh a scientific culture in the general public.

Alberto was involved in risk communication, and addressed how information on religious belief was used to disseminate science information.

> **Alberto:** … one of the action point *[sic]* is to ensure that the information education campaign is actually done, the community based uh, level. And one of the innovation *[sic]* that we did was actually, we did not do the IEC into the, uh, community itself, we did it among the priests, the pastors, and the imams … And they were the ones who actually told the people how these things are. And why is that so? Because people in the community tend to believe more their pastor, their priest, their imam, compared to the national government. So, uh, religiosity, it's uh, something given eh, because, whether you like it or not, it's already there eh.

Carlos also talked about a hypothetical situation involving the role of religion, and one that engineers might face when working on their projects in the real world.

> **Carlos:** … because your values are higher than engineering right? So, there, so uh, sometimes you go for a win-win solution, but sometimes, it's not possible. No, it's just impossible to try to, you try to build a geothermal plant in a mountain that's considered to be a god by tribespeople. How will you solve that?

Some of the participants believed that religion had given them values that they considered consistent with scientific work. For Hipolito, religion had contributed to his sense of ethics.

> **Hipolito:** I think it helps me … have some ethical *what*, perspective of things. That's why I say that it's important to be honest, things like that.

Rita believed that doing scientific work for a greater good was consistent with religion.

> **Rita**: I mean, what about religion? Eh, my scientific work is actually good (laughter) so what about religion?

To Ofelia, having religious beliefs meant that one had innate goodness that allowed her to feel the need to help people.

> **Ofelia :** The goodness. Whether it's Christian, Muslim, whatever you abide by – um for me … my Catholic religion has been very helpful, because the stigma of being able to reach out um to people, many of my friends, I mean – many of the ones that I have in the area, are those from the church.

Nadia, a Catholic, had been open about her faith during the interview even before she was asked about how religion affected her work. She talked about how religion had helped her cope with the stress of school when she was completing her doctoral degree.

> **Nadia**: Going back to when I was doing my Ph.D., uh, uh I don't think I'll be able to finish my Ph.D. uh without this Catholic community, because I was able to meet a Catholic community in the chaplaincy in the university and they're able to give me strength … It took me some time to understand the words of Jesus … So it is when I was weak, or I am weak, that I knew that I'm strongest cause you – Jesus is there … I mean, faith for me is very, very important because you only have this much strength. Your human strength is limited, but His strength is endless, infinite.

Nadia also went on to talk about how going to Mass often helped her even in her present job as a researcher and administrator. Like Nadia, Dina, also a Catholic, was religious and went to mass often. She also added her own insights about prayer.

> **Dina:** When everything fails, just pray, give me guidance, give me serenity, give me peace (laughter).

Dina belongs to a branch of the state university that concentrated on medicine and human biology. This particular branch was also headed by a deeply religious chancellor who insisted on daily masses in the university chapel. Dina also shared how prayer contributed to her work as a scientist.

> **Dina:** In fact if I may say so now, tying it up with science, there was a time in the 1990s when we were trying to – to make … cell lines that were dengue infected, to grow, and I prayed over them … You really pray over the cells so that they grow. If you don’t pray for them, they won’t grow … And uh, I have also a group … an unofficial advisory

> group of my friends – if we have a lot of problems, we really come together and pray for each other. We do that. Because you really can't – with so many issues – you know, it's tiring, and then we support each other. But every time we go back to prayers. It's really prayer that keeps us.

For some of the participants, religion was not only a way to cope with stress, or an escape when everything else had failed in the laboratory. To them, it seemed to match the values and norms of the scientific discipline. For instance, Ofelia, a Catholic, talked about the value of the love of knowledge when she relates her own experiences with religion.

> **Ofelia:** So I guess if – if a person really abides by the good – the – the principles of – of the religion that one possesses. Actually that's just basic human nature, the thou shalt not kill, the Commandments. I mean, it's common sense, it's common sense. However, and this I learned from the Catholic, if we try to understand more and have that clarity of conscience by being able to define, in greater proximity, the good and the bad, then we become better – better persons. So – you learn to understand the why – and that's why I think with religion, religion and science really don't contradict. Because in religion, we – there are things, the Ten Commandments for example, that say: thou shalt not kill. But why? That's your question.

In this case, Ofelia did not see any clash between religion and science because both ask the same "Why?" questions, and should encourage people to find answers to their questions. She continued with her discourse on religion and science, and how they were tied by a love of knowledge:

> **Ofelia:** Because you said, even the Muslims, even the Christians, they say: thou shalt not kill. But people have redefined life, but one needs to understand why that is the case, and you can use the science argument as well. So I guess when you say, does your basic underlying – pressure – does religion limit you as a scientist? No. because when religion says something, scientists something, one needs to understand why it is being said. And I – one needs to have – one also needs to have the humility. The people before me, whether they are theologians, whether they are scientists, must have said things because there are reasons.

To Ofelia, however, the evolution versus creation debate was not an issue:

> **Ofelia:** Now for me to be able to make decisions, I need to take a step back and understand the reasons why those proclamations, principles, scientific theories were made. Even creation versus evolution. To me that is not even an issue. Because God is timeless, so the sixth or seventh day is not even an issue for me. And we – we talk about the creation of the human being or Adam and Eve. It is the fusion of the spiritual soul into a perfectly – or a made ape for example, the Homo sapiens or the modern human, that is modern human – so it's not – it's not even an issue for me, creation versus evolution

Tanya and Flora, both Catholics, also talked about the love for knowledge, and the implied value of humility that brought about by religious beliefs. For Flora, a mathematician, a deeper study of mathematics made her even more religious.

> **Tanya:** … I think that uh, religion has its place in um in a person's life, so I – I uh – believe a person should hold um his own personal religious beliefs … but it is this recognition that there are uh so many unexplained … aspects of, of human life and nature. Uh, and you're really not sure uh, beyond one's uh life what's ahead. So if it's a recognition of – that your mortality, and it's a kind of a uh humble um way of uh accepting that uh, it's not possible to explain everything uh in one's lifetime and one doesn't know what's ahead.

> **Flora**: … I really have to acknowledge ok, someone who really provides all of these ok, I mean – all – in all fields of life…this simply tells us that there is a g – there is a Supreme Being, ok? Responsible for all of these….Well, I think uh that must be due to also – my Catholic upbringing. So basically I was taught as a child that uh there is a god ok, who is – who has created everything, ok, created man, and uh created uh nature, and that he is also the source of – objective reality, really – everything that – everything that we know of, ok, everything that we are, everything that we see around is a creation of God. Ok, and so my uh my – my journey through mathematics has, as I said, made me more convinced.

To Glenda, a Catholic, deeper faith came with age and coincided with scientists' need to serve society:

> **Glenda:** … I find that as I get older, my faith deepens. I spend more time praying now than I did then, 20 years ago. And I would like to think that what I am doing is part of my mission from God. I mean

> that's too – that's really high-falutin … but I would like to think that I am help – I am – our research in the lab will eventually be helping Filipinos. I think that's a mission from God. Right?

To Kampo, a Baptist, religion coincided with the values of a love for knowledge, humility, and an awareness of obligations to society. As a scientist, Kampo believed that he had very little power, and therefore had to remain humble no matter what findings he discovered.

> **Kampo:** Yeah - I believe that God created the earth to give you responsibility just to discover, discover God's uh creation … or wisdom, just to discover a bit of his wisdom. So don't think too much that you – if you understand these things, you are already God or you are more than God, or you are – you are just discovering some things. So you - you must have that limit where you could not go beyond those areas. And if I can't do it, others will do it, another will be used to – to do it. So you give more – you'll be more satisfied, he is just revealing small things for you. And he will be revealing this next to that – next person, so don't be stressed too much, or don't solve the problem of the Philippines by you – yourself when you are here just to – just to contribute something based on your ability, your capability.

Kampo then went on to connect environmental problems and, consequently, his research on salinity, to the biblical account of the Fall of Man.

> **Kampo:** All what we're doing now is just the result of the destruction of the – of the start of the very start of … creation … sinfulness of people … So maybe salinity is part of that curse. The toxicity, weeds, problem of water, so you have to work hard to like – the way I see it, the genes of the ideal plant were in the Garden of Eden. Because of sin, he scattered the genes, the good genes.

Kampo has been working on the genes that enable plants to withstand high-salt soils. In his interview, he talked about finding all the scattered good genes and placing them in one plant. He had even presented his ideas on the genes of the Garden of Eden in his job interview. Like many of the other participants, he had no qualms about talking about religion because many of the scientists he knew also belonged to his church.

What does it mean to be a civic researcher?

In this portion of deductive analysis, the researcher read through the data and highlighted portions relative to typologies that addressed Trench's (2008) classification of science communication, Swidler's (1986) culture-as-toolbox model, and Lam's (2010) boundary-setting framework. These typologies were presented earlier in the Methods section of this document, and are detailed in Appendix G. When the data were completely coded using the typologies, the researcher summarized the ideas under each typology. The researcher looked for overarching within the summaries of the typologies. These overarching themes were then used to recode the already marked data.

These overarching themes were then used to formulate generalizations, which were used to answer the research questions. These generalizations are presented below, along with quotes from the participants and a discussion of the quotes in context.

What science communication models do the researchers follow?

Trench (2008) provides several base models for a science communication framework. The base model of dissemination, for instance, holds science in high esteem, defends science, and markets it so that an ignorant public can be persuaded to accept and support it (Trench, 2008). The base model of dialogue, on the other hand, emphasizes context and audience engagement, where the public provides feedback that scientists can use in their practice (Trench, 2008). Finally, the base model of conversation stresses deliberation and critique, where scientists and the public actively work together solve and learn from issues (Trench, 2008).

Some of the participants in this phase of the study were already experienced in dealing directly with the lay public. For example, Benigno, a civil engineer, works through online channels to share information on buildings and structural engineering. Dina wrote a children's book on polio and how scientists are working to find a cure for it. Glenda goes on road shows with her college to promote engineering careers in local high schools. Lapid speaks about various health issues through public forums. Tanya founded a column in a national newspaper, which provides a venue for local researchers to write about their research. Rita and Pedro had contributed to the column. Sarah gives radio interviews on science-related issues. Dina, Eva, and Julia talked about genetically modified organisms at various public symposia.

Based on their answers to interview questions, as well as tallies of responses to questions regarding science communication and risk communication (Table 4.2), the views of the scientists in this study are consistent with belief in the dissemination model of science communication.

Most of the scientists believed that science is the most trustworthy source of data. Alberto, in particular, noted how scientists needed to provide information; couching knowledge in context was not always an advisable way to communicate science because laypersons might not understand science information otherwise.

> **Alberto:** I can run a numerical model now and it can tell you what the forecast will be for the next three days. But if I tell you it will rain if

> things don't change, then I'm not communicating anything right? Because I, I, you, you leave the, the burden with the *what*, with the recipient.

Nadia believed that scientists needed to communicate directly with the public, since their experiences in the laboratory made them the best equipped to speak about their work.

> **Nadia**: Yes, because they're the ones who know, and they're the ones who are hands-on. They're the ones who make the – who do the experiment, so they should be able to translate it or tell it themselves.

Nearly all the scientists believed that the facts spoke for themselves, and that a good grasp of scientific knowledge was what was required to successfully communicate science facts to the public. Quirino, in particular, talked about the importance of adhering to the facts in response to many of the interview questions.

> **Quirino:** I would say that well – probably it should be done uh gently but you just state the facts.

Sarah likened the language of science communication to that of international scientific journals. She actually suggested a correction to one of the interview questions on science communication because she felt that the term "science communication" needed to be qualified as "the scientific communication of scientific information."

> **Sarah:** Because there could be some misinterpretations *[sic]*. That's why you need to be very exact in your terms. And then sometimes you may be able to use words which do not mean the real fact, the real information ... Because I'm also a member of the – the editorial board of sci – certain international journals. We choose exact words to mean certain phenomenon or certain interpretations. So we use exact words.

When asked to define risk communication, the participants' responses were similar to those they gave regarding science communication. Many believed that only scientists who could speak well in public should be allowed to do so. Hipolito, a marine biologist, even made a joke about the personal consequences of ineffective communication:

> **Hipolito:** Again, they shouldn't, but if they're able to communicate it, uh, they are good communicators, then it is good. But if they're very bad communicators, they will put their selves at risk (laughter).

Some of the scientists believed that science communicators could help build bridges between science and the lay public. Nevertheless, they still wanted science communicators to work closely with scientists before attempting to communicate science or risk to the lay public.

> **Julia:** But we should make ourselves available for consultation so that the risk communicator will get the true facts, or at least what is supposedly true at that point in time based on your present knowledge. Because– it – it may be easier, to do – to let the professional do the communication part, but the scientists would be needed to guide the risk communicator so that the risk communicator does not make a sweeping generalization.

Alberto wanted scientists to work with communicators: scientists would arm the communicators with science, which he believed to be the source of trustworthy information. His view is consistent with the dissemination model of science communication:

> **Alberto:** It's – it's always the case. Why is that? Because the scientist will be the one to give the weapon, quote unquote, to the risk communicator. You know, it has to be science-based, and uh, who will be doing the science? It's the scientists. So uh, it's a partnership.

In line with a belief in the trustworthiness of scientific fact, Eva wanted science communicators to be highly educated in science, or they would not be able to communicate it well.

> **Eva:** So it's a little bit frustrating because uh, you have to have a certain knowledge of science in order to write about it – conf – confidently ... I think for, for science communicator – communication – or for science communicators, I think they should have some solid background in science. And if they have advanced degrees in science, so much the better.

Many of the scientists believed that effective science communication would result in the public accepting science and then thinking like scientists – views that are again consistent with the dissemination model. In the dissemination model of communication, the lay public is seen as the recipients of knowledge, whose views and behavior can be changed. This is echoed through many of the responses, and exemplified by Kampo's claims.

> **Kampo:** I think successful science communication is when you could uh change the view of people when they are already closed. For example GMO, GMO ok, all the media will say what is negative about GMO, or this one, they're all closed. Now if you're a science communicator then you could communicate with people to clean up their mind or just open their mind.

The participants also mentioned how "talking down" or "going down to the level of the layman" was difficult.

> **Dina:** If you're talking about communicating to the layman that's more challenging, you have to come down to a level that is simple, that it can be understood, and yet they won't be scared, they'll embrace it, and also know that there is a possibility – that there is such possibility for risk. It's coming down to what the levels are – it's hard.

Such views are consistent with the "us vs. them" philosophy of the Dissemination Model. Sarah, Glenda, and Tanya believed that scientists could change society itself.

> **Sarah:** I think it is the duty also of the scientist to help the people develop this scientific thinking.

> **Glenda:** So I believe that if scientists and engineers communicate to the common person, a lot of things could change. Maybe people will start thinking scientifically.

> **Tanya:** … our students ... they tend to um, just um pursue careers … they want good financial returns, so they will, they will tend to pursue the um, the easier path. So when I started [the newspaper column] … so my um, introductory article, I tried to put it as lively as possible, and I said, uh, well we're starting this column so that we can uh encourage our youth uh to um become interested in um science as an alternative to song, dance, you know, sports, uh, business, um, food, religion, uh – art, etc. TV … the quality in education is not very good, the orientation is not towards the life of the mind, but it's really for the satisfaction of the senses and … physical satisfaction. So you know that – so you know science … honestly, it requires more, more of a mental life.

According to Tanya, science communication would not only allow people to receive valid information, but raise their appreciation for and knowledge of science, and, finally, change how society thinks and behaves.

> **Tanya:** Science communication should effectively … relate to um, to your recipients, the…scientific uh results uh that are valid … So um, if we should um, raise the, the science literacy, appreciation of the recipient, and then you know, in turn, and then the heaviest impact … science should change the way the … community, the country um, views the natural world. So it's – it's really um, what do you call this, knowledge-based, knowledge-based um culture and a society, rational – reason-based … human beings and the way they view nature.

Not all the scientists, however, insisted that society had to listen and subscribe to the ways of science. Some of the scientists also believed in some elements of dialogue models of science communication. For instance, while Kampo believed that science communication could change people's minds, he also believed in modeling his research on what people needed – a task which he had already done before, and with the help of social scientists. Quirino saw science communication as a way for scientists to receive feedback on their work. Once they received feedback, then they could continue their research.

Ofelia summarized the dialogue model as she invoked the familiar image of the “ivory tower” of science.

> **Ofelia:** Because that crosses the line that's your Goldilocks *[sic]* bringing down her hair from the ivory tower to let the general public get up to the tower and understand their science, right? I mean, I hope it's not very high. But – but it has to be able to reach out, because it is actually a win-win situation, because we learn to communicate in that way because the scientists are able to help address the concerns of the general public – in the way that the general public has the problem.

With a few exceptions, it appeared that the scientists believed that their knowledge and expertise still made them the main source of knowledge in science communication. Scientific truth was still held in high regard no matter who the audience, and the audience needed to listen to scientific fact.

What is the culture of the civic researchers?

Swidler's (1986) conceptual framework defines culture as a tool-box. A culture provides its members with the coping tools and mechanisms necessary to deal with change. In this research, the participants were asked various questions that allowed them to talk about the tools that they used to cope with changing science. They were asked about science in school and how their views of science changed over time. They were asked about their responsibilities and jobs, their views on the scientific method, and their views on science communication. They were asked for their views on social scientists and the social sciences. While all of these questions provided insight into the changing scientific culture, they also provided statements on how the scientists worked in today's research culture.

In this section of the dissertation, several aspects of scientific life will be examined: how the culture of science has changed, what the scientists believe their new duties are, the tools that scientists believe are helping them cope with this change, clashes between the traditions of science and how science communication is conducted, and what tools the scientists believe they still need in order to deal with the changing world of scientific research.

1. Today's science demands that scientists take on different duties outside the laboratory: they need to communicate to the public and collaborate with researchers from other fields.

> **Alberto <field notes>:** The age of the rule of the natural sciences has ended. It is all about people, so many different scientists have to come together.

Alberto's statement, which he gave after the interview, and which appears in the field notes to his interview, encapsulates how a once closed, confined science is slowly opening its doors to other fields. Nearly all the scientists discussed, in one form or another, how such changes were under way in their own branches of research. For instance, Lapid referenced Western views of science in disengaging from society to ensure that it was "pure"; Flora talked about how Western views of mathematics were now set alongside native ways of carrying out mathematics; and Kampo, Ofelia, and Tanya talked about how scientists were taking on more responsibilities outside the laboratory.

> **Ofelia:** You communicate through the media because you need to – to – to communicate all that. You need to correct if there is anything erroneous. Then you're also given administrative stuff because um, science is not only just being in the laboratory but also is managing the finances um, that – and then you're also – you want - a certain

> proportion of your work is also in terms of extension, in – in being able to do the services right.

The participants also acknowledged that scientists were required to look at the social dimensions of their work. According to Benigno, the field of engineering had extended its responsibilities beyond funding, and into sustainability.

> **Benigno:** But now, there's now a, a shift - not really a shift – an extension of responsibilities. So for example, responsibility to the environment or sustainability – that's what is now ... being emphasized. So, originally, the traditional... role or objective of the civil engineer is ... safety of structures ... but now it's been second to sustainability

For some of the scientists, fully engaging in research itself was a new development. For instance, Pedro talked about how colleges and universities needed to engage in more research and not simply teaching. Glenda and Flora shared how their university system was slowly taking on more research work as its scientists realized the value of laboratory work.

> **Glenda:** I'll tell you this: 5 years ago, our college, very few people are engaged in research. Then [the] administration started uh coming up with this uh requirements for tenure, promotion, etc., you're required to publish, then they started with the international publication awards, etc. so the message was clear. We have to publish, we have to do research; there was assistance at the beginning from our college because if I compare my honoraria as project leader ... I receive PhP4200 a month. If I do a lecture, just a lecture, in industry, for one hour, I get PhP5000 per hour. If I do consultancy for industry, my current rate I think is $250 per hour. So how can – can uh – research compete with those other activities? Very simple: people love to teach. Certain people love to teach. And if that's the way to stay in the university, they will engage in R&D.

> **Flora:** Because uh, at least uh, as far as I know, in the academe, um, it is slowly being recognized that research could enhance teaching. Ok? Because through research you are able to generate, help generate new knowledge, and that new knowledge can be plowed back into your teaching.

Concomitant with the increased emphasis on research is the constant demand for research that will yield useful products in the shortest amount of time. This demand has been addressed previously; its effects on research will be explored later.

The participants also discussed how they were tasked to communicate science to the lay public. To Alberto, the task of communication was meant to provide science-based information to laypersons in order to garner their acceptance of technology.

> **Alberto:** But when it comes to public perception, to social acceptability, almost all of the projects are actually disapproved because of that. Because you have to make sure that the people are on your side. You have to make sure that they're on board. And if they don't understand what you're going to do, how it will benefit them, then there's no way that you can get their acceptance … Almost all of the studies, they're getting disapproved because there's no, uh, uh, social acceptability.

Like Alberto, Tanya acknowledged the importance of communicating science. To Tanya, communicating science meant sharing information with those who lived closest to biodiversity hot-spots.

> **Tanya**: ... it made me realize that ... the researcher must recognize that ... there are other stakeholders in the case of uh, biodiversity based research, you could have local communities living near the biodiversity who are the ... guardians of the biodiversity, some of them are informed, some of them are not, and so it is your responsibility to recognize their rights over the biodiversity, and to um, share information with them.

While Tanya saw communication as an ethical and practical responsibility, Glenda framed it as a “soft skill” that was connected to how researchers needed to carry out research that would yield useful products.

> **Glenda:** But today, we know that engineers they go – also to the point where they innovate on new things – on – on old things – innovate. They also go into uh marketing. 'Cause – an idea is just an idea, and unless a lot of people benefit from the idea, it's useless. So they also have to learn all these new soft skills.

While Glenda saw communication as a means to market research, Carlos saw it as a skill that engineers needed for their clients:

> **Carlos**: In the past, it was the manager that people talked to, but more clients now need to talk to engineers. Now – that – uh – that I guess uh, heightens the need for good communication skill.

Ofelia believed that the task of communicating with the public was actually built into research.

> **Ofelia:** So one needs to also address not only the technical part, the ethical part, and the social part. Particularly when you're doing science that has um, well all of – all the things have ... social impact, but we cannot end for the scientists, we cannot end our work only on the technical part because that would be the scientist in a lab coat, with glasses, in an ivory tower.

While the participants agreed that communication was important, the participants were willing to be involved in it in varying degrees. For participants like Isabel, Kampo, Pedro, Quirino, and Rita, scientists needed to simply try communicating with the public because they knew science best. For participants like Benigno and Sarah, scientists needed to be more directly involved in science communication to avoid mistakes by the media. For the rest of the participants, more tools, such as training and partnership with other fields, were needed so that scientists could meet the requirements of the current science culture. Such tools were mentioned even by the participants who believed that all scientists needed to communicate with the public.

2. The way that science communication is conducted clashes with the traditions of science.

Some of the participants disclosed how the practice of science communication clashed with scientific work. For instance, Dina and Julia did not have time to communicate with the public, a fact that was compounded by other problems in science communication:

> **Dina: ...** we cannot do enough because those who do true science … are busy with so many other things. While [the NGOs], their communication is precisely geared to cause trouble.
>
> **Julia:** And the people who are up on the science are not very good risk communicators, 'cause one, we do not have the patience; two, we sometimes actually do not have the time, because that's not what we're supposed to be doing; three, I think it's more like, we do not have the background in communicating and actually touching bases with the lay audience.

The participants identified three clashes in these statements: a clash between communication work and scientific work; a clash due to lack of communications training by scientists; and a clash amongst the different parties that carry out science communication. First, the clash that occurs between communication work and scientific work can be thought of as a matter of obligation: scientific research takes precedence over communication, which researchers might view as a responsibility, but not a job. Second, a clash might occur due to the fact that scientists have not been provided with communications training, an important tool when interacting with the public. Third, another clash might occur due to disagreements and lack of communication amongst the different parties that carry out science communication. These clashes were mentioned by the rest of the participants.

Nadia, like Julia, Dina, Alberto, Kampo, Marina, Lapid, and Ofelia, recognized that working with lay persons was difficult.

> **Nadia:** And it's too difficult ha, for a hard scientist and then bridging it to the social science. You should really have, uh, talent, *right*? Isn't it hard to work with people?

The participants' perceptions of working with people emerged when they were asked about the social sciences. They believed that people were not easy to control or study, and that dealing with people was far more complicated than engaging in laboratory work.

> **Alberto:** So in the process, they give you, uh, you know, a human factor. Tells you what uh, the perceptions is – sometimes, you tend to see things in black and white, but there might actually be green, and, and these are the inputs that come from the social scientists.

> **Benigno:** ... it's harder to understand the human mind eh, or human behavior, right? It's difficult, it's uh unpredictable, right?

> **Julia:** ... in the scientific activity, things are more predictable, and they're more neutral in terms of emotional and social uh, involvement, so – it's nice to get in there if you want to escape from people, if you want to escape from humanity then get into sciences.

The "escape from humanity" is echoed by Carlos when he talks about how some students self-select when they enter the field of engineering.

> **Carlos**: ... they might be into engineering in the first place because it's a quiet profession ... it used to be in your drafting table, designing things, not talking to anybody, there with your computer, moving your mouse, not talking to anybody. So engineers are not really great communicators – we are – we are not so – yeah (laughter) - it's so hard for them – it's not just the Philippines. Even in the U.S. they complain about that.

To many of the scientists, scientific training does not always prepare scientists to communicate. Julia talked about the unique attributes of scientists in detail, and how science culture clashed with how science communication is conducted.

> **Julia:** We also want to get more data every time we want to make a conjectural statement, right? ... 'Cause sometimes the newspaper you – you read things that conclude uh, make certain conclusions but are not supported by data. So I think that's basically the culture of being more – I wouldn't say combative, being more um, difficult to please ... Because sometimes, the data may be enough for some people, but not enough for you, especially if you're talking to the experts.

The scientists also believed that culturally-based attitudes made science communication an even greater challenge. For example, Marina discussed how the inability of Filipinos to take criticism also contributed to the lack of published research in the country.

> **Marina:** ... the ability to discuss openly – the ability to uh accept criticisms, although that's so difficult for the Filipino culture ... that's why a lot of people don't publish their work ... when they get bad reviews, they don't want to continue. They become static, their work becomes stale, they don't want to show anyone their work.

The challenges of communication were not confined to the difficulties experienced by scientists themselves. Dina mentioned how science communicators could "mess up" their message. Some of the scientists, like Nadia and Quirino, specifically pointed to non-government organizations, or NGOs, which they felt often drowned out the voices of scientists and made science communication an even greater challenge. Kampo thought that NGOs did not only make science communication difficult, but also stalled research because they were not as open as scientists.

> **Kampo:** Because we're open, they're not open. And they are just doing – criticizing but doing their own science ... we spend plenty of our time just to – to answer their questions … *it was too risk conscious*

> *that we've suppressed the products that science should have come up with.*

Tanya and Pedro talked about how supposedly objective facts could be used by other interest groups to push their own agenda, which clashes with how the scientific culture holds facts and objectivity in high regard.

> **Tanya:** ... a person can really communicate objective science, it could also be used by interest groups right? To validate to certain things that look like science but are not. There's always lots of controversy and that's so important.

Additional challenges were identified as coming from people who claimed to represent scientists. When the topic of the mass media was raised, many of the participants began to talk about their frustrations. For example, Eva thought that those who were tasked to write about science did not know enough about it.

> **Eva:** Sometimes, in many, many cases, articles in the newspapers are very misleading because uh, the writers have no – probably very limited background in science. So for example, when it comes to stem cells they just add and add and add paragraph on paragraph – when on their own, the paragraphs would probably stand correct. But when you combine them in a particular fashion, they are actually very, very misleading. So it's a little bit frustrating because uh, you have to have a certain knowledge of science in order to write about it ... confidently.

Eva continued with a specific criticism of local journalists.

> **Eva**: So I think there's really a scarcity of science communicators and the errors that are being propagated by the media need to be corrected – it's always an uphill battle because people are writing on something that they do not really know about ... You can find only very few real journalists in the Philippines, they do not do their research.

Julia agreed with Eva's assessment.

> **Julia:** Because that's ... a problem eh, the people who are supposedly ... to be tasked with risk communication are not up on the science.

Sarah and Glenda also voiced their frustration with the mass media and shared examples of how media had failed to report science correctly. According to them, science needed media support in order to proceed, but the media also needed to improve.

> **Sarah:** That's where I get irritated, with the media ... They uh only give what they want people to give – to – to – that's how they see it. And then the – actually, they shape the minds of the people. However, eh, they get ahead of themselves, they don't give the, what the uh, scientist is saying, uncropped ... The scientist should not be edited. Because you will have misinterpretation. That's why my frustration is the media.

Other participants, such as Marina, Tanya, and Dina, also dealt with the issue of sensationalism in the media and discussed how communication often failed because of media biases. Glenda also talked about how the media twisted the facts provided by scientists.

> **Glenda:** Somebody interviewed uh our … professor about ... *what are the effects of microwave radiation on people?* But it was scientific, he said, according to the laws, this should be the maximum amount of watts so that we get this so-and-so thing. Factual. When it came out on TV, they asked, do you want to get cancer? ... I said, why did it come out this way?! So we – we have a problem with our ... media.

Despite these clashes with tradition, the scientists believed that they could still communicate. They had already mentioned several tools that the science culture had provided them to communicate, and they were also aware of what they needed to do and have in order to keep their lines of communication open with the public.

3. Science already provides scientists with some of the tools needed to cope with change, but scientists believe that they need more tools and resources to help them, such as social scientists, science communicators, and communication training.

The participants believed that the changing science culture and an increasing stress on communication, while sometimes clashing with their own research obligations and ways of thinking, could still be dealt with. They called upon their own training as scientists as they talked about the tools that were needed to not only carry out science communication, but improve it as well. Sarah believed that being scientific, on its own, prepared scientists to communicate with the lay public.

> **Sarah:** You should be scientific in communicating whatever you like, because it's science that you are communicating. That's my concept.

As mentioned earlier, the participants believed that reliance on the facts would produce effective science communication. Participants such as Sarah, Lapid, Julia, Dina, and Quirino talked about how the facts needed to be brought to the lay public. Another scientific value that the scientists mentioned was that of their obligation to society. Participants such as Ofelia, Eva, and Julia believed that this obligation encouraged them to communicate with the lay public.

> **Eva:** But I think we have a responsibility, and particularly when we receive people's blood in our research, that uh, we have to be very effective communicators. And uh, if uh, if you have scientific results, you should be able to communicate your scientific results, be it orally, in conventions and uh, public fora, or in um, scientific journals that are um, refereed by colleagues. So you can have a verbal form of communication, you can have an oral form of communication – but it is essential for all scientists to be able to communicate well.

The participants also referred to the value of openness, and, consequently, the norm of sharing data as impetus enough to communicate, whether to fellow scientists or the lay public. Communication, they said, would allow them not only to network with more scientists, but give the research field a chance to develop.

> **Dina**: ... you should be open in science. That's how you get ideas. You will eventually see if something is viable or not, by exchange. Because you have to face the fact that there's a lot to learn, there's a lot of knowledge out there, it's not something that can be handled by one person or a few only.
>
> **Isabel:** ... start by proving their ... capability by publication, because you won't simply get linkages if you don't have a track record. So start with yourself – and then you can start getting uh, funding, and collaboration.
>
> **Marina**: ... you should be open. You should be willing to share also whatever you find out – and that's why publications are so important for growth.

While the culture of science had provided the scientists with the means to push through with collaborative efforts, the participants nevertheless acknowledged that they still needed more tools for science communication itself to succeed. Participants like Alberto, Julia, Marina, Ofelia and Tanya believed that bench scientists needed to partner with social scientists and communicators in order to produce truthful science communication. This partnership entailed the scientists providing the information to science communicators, the social scientists measuring public perception and acceptance, and science communicators packaging the message.

> **Marina**: ... a really technical scientist, he can work with somebody who can make something less technical ... and then, uh, the mass comm people – sometimes they have too much ... hype. So – they have to pick the communicator, not just anybody – you don't feed things just directly. You filter through, you pick who will transmit.
>
> **Ofelia:** If some scientists are not able to [communicate to the public], then there should be a support system where the science communicators would take part. And assist. Or actually even play a crucial role. *If he/she really can't do it, can you do it for the scientist?*

> Or - or (laughter) will provide, you know there are creative ways, ha, creative ways of packaging information. And because scientists many times are very much involved in the laboratory sometimes, that – the technology outruns them. And so it must be a different field that packages this um to be able to assist in getting the message across to – to – to the general public. So I think there is – there's a role for – for each.
>
> **Alberto:** Because they have to go to the culture, you know, they have to immerse themselves, look at the culture, look at the environment, give options, and make sure that people, not only understand but internalize the whole thing. So the social scientists are important. Ah, I ever since, I, I, uh, I have, uh, uh, felt strong about that, that natural and physical scientist cannot do it on their own. You have to make sure that the other branch of sciences are *[sic]* actually part and parcel of the whole thing.

Participants such as Sarah and Dina talked about how training had helped them communicate science. Most of the participants agreed that scientists needed to be trained before they were allowed to communicate with the lay public. For participants like Carlos, Dina, Eva, Flora, Glenda, Hipolito, and Lapid, scientists still needed to try to communicate their findings to the public whenever they could.

> **Eva:** I don't think all the scientists can do this, but there are certain scientists who have a gift or a training for this one, and it is very, very important for our science policymakers and some of our scientists to be involved in the process of uh, in explaining to the public the results of these experiments and the breakthroughs that we are experiencing at the moment, how it's going to impact their lives.
>
> **Tanya:** ... sometimes scientists are not effective communicators whether through uh uh written or oral communications ... so um, maybe you can – let at least the science majors should, well enroll ... or courses should be offered to scientists to um make them more effective communicators and um you know science journalists, and I think this is being taught already.
>
> Julia, however, voiced her skepticism with communication training.
>
> **Julia:** I don't really know who a risk communicator could be, whether a scientist should do it, or it's easier to train, let's say uh somebody with a communications degree to communicate the risks ... Can you imagine? Going – let's say, as an undergraduate student, we have a

> three unit course on risk communication, I'm going to fail! And then here's this person telling you to do communications and the – the person doesn't understand your science, I don't really – don't really know how to do that.

Julia also regarded communication through mass media channels as a talent that was innate to scientists rather than a skill to be learned.

> **Julia:** So we don't have the skills for mass communication, I think, if ... we do, that's more ... of – innate talent, and ... instinct, rather than a considered way of imparting information.

What boundaries do the scientists set between themselves and the lay public? Themselves and communicators?

Lam's (2010) boundary-setting framework was originally designed to describe the boundaries that participants perceive between themselves and industry. The framework is meant to characterize participants based on how they perceive their roles to be in society, and how their work is affected by external forces.

In the current research, the original framework is altered to describe how participants might differ in their perceived boundaries between themselves and the lay public, social scientists, and science communicators.

1. The researchers are Communicating Hybrids when dealing with the public: they are aware of their social obligations to communicate but experience no role identity tension.

According to an adaptation of Lam's (2010) boundary setting framework, researchers can be categorized into one of the following four types on the basis of their perceptions about dealing with the lay public: Type 1 (Tight Boundaries) seek to protect science from feedback from or involvement of the public; Type 2 (Traditional Hybrids) test and maintain boundaries but feel role identity tension; Type 3 (Communicating Hybrids) negotiate and expand their boundaries but feel no role identity tension; and Type 4 (Communicating Scientists) link their work to communication and fit research following external demand and feedback.

Based on the data, a great majority of the participants can be classified as Communicating Hybrids. They are committed to the norms of science, and are also committed to communicating with and serving the needs of the lay public. They are secure in their identities as scientists even when they are tasked to take note of public interest and acceptance. Hipolito believed that serving science and serving the public were not mutually exclusive.

The participants are committed to science communication to varying extents, as evidenced in the previous section. Some, like Hipolito and Alberto, are willing to be guided by social scientists so that they can carry out scientific research according to what the lay public wants. Others, like Ofelia and Quirino, are willing to listen to feedback on their research. Still others, like Eva and Nadia, believe that communication is in place for people to gain a greater appreciation for science.

Tanya and Alberto believed that research that has a direct impact on society can benefit the country as well as the scientific discipline.

> **Tanya:** ... But then there are also these scientists ... who contributed in other fields uh, in other levels because they moved ... basic science forward by working on the applications of science that have a direct impact on humanity, whether it's in health, agriculture, or environment.

> **Alberto:** If you're going to look at the history of almost all countries, most of the development are [*sic*] basically based on science and

> technology. So ... that's why I'm saying eh, you can actually do all the research that you want, but if this is not translated on the ground, *then what a waste,* it's like a lost investment ... they have to actually be sure that they are contributing to national development. Because if not, uh, then you end up with what? Even in Third World countries, they're not doing science for science per se 'no? They're making sure that it's going towards policy, to – towards a particular technology, towards something that can be utilized on ah, uh, on a day-to-day living. So that's the, uh, critical role of science. As a matter of fact, uh, make life a lot easier for almost everybody

Benigno believed that engineering, his research field, is defined as one that helps people directly, which therefore translates into a specific research mission.

> **Benigno:** Uh, say with the engineering, if we define it strictly uh, with the profession … it builds society … if you look at it, the scope of the work of engineering, it, it's really building the quality of life of people … someone said … do we really need lawyers (laughter) to build quality, the quality of life. *No, right? ...* if you look at engineering, at civil engineering, or at engineering in general … it's really how to … not only survive in the world, but building to raise the quality of life … that's what I see as the … role of engineering.

Marina and Ofelia believe that science is of little value unless it is applied.

> **Marina**: Science as a whole – should really do things for the benefit of mankind. There – that's why we're trying to uh trying to bring science to people, science and technology to people. Because if you can't help people, what you are doing is useless! ... eventually the – the research will always relate to people. People do it and uh built it up, but it should be uh, go back to the benefit of mankind.

The participants were also aware of their obligation to communicate science to the public. There was no role identity tension in their statements and they were able to reconcile their various roles. The participants were still secure in their roles as scientists, as those who produced the information; and possible communicators, as those who could bring the knowledge to the people. Tanya believed that the task was also a moral obligation.

> **Tanya: ...** I think that ... scientists have a responsibility or duty to ... advise ... the leaders of communities and nations on uh matters that could affect the

> uh. survival, the health, the quality of life of its citizens. So there's a kind of morality to it.

Pedro believed that publishing one's work had long-term implications for both research and society.

> **Pedro:** The fundamental responsibility of the whole thing is to put the knowledge out because we never really know, it could be abstract, it's a mathematics that was done in the 1960s which decades later proves to be invaluable for digital cameras or something like that. This is a true story which I always tell people. You never really know how useful your work would become so, and you never know generations from now, years from now, there could be someone who comes around and figures out a way to use your work ... So I think fundamentally the responsibility is for the knowledge to be shared. Because once you – once you die, for example, and you know something, that's lost knowledge which could have – could have solved the problem later on.

Some of the scientists were also willing to listen to feedback in order to fuel their own research. While this characteristic is consistent with Type 4, their overall perceptions indicate that they had no role identity tensions: they were secure in their role as knowledge providers, and they did not feel that their research goals were being compromised. For instance, Ofelia made it a habit to read the newspaper so that she knew what questions needed to be asked in her own research, and recognized that she also needed to listen to the public.

> **Ofelia**: … something that I learned throughout the number of years that I've been here, is that when scientists learn to listen it's not just us talking, it's … to be quiet – many times and listen to the public, to your stakeholders. Because they might not formulate your hypothesis, but their perspective in the problem – because it is their problem, not yours – is very, very impor – important in the final formulation of the projects by which you will focus your entire – well, not your entire career, but at least to the present moment.

Kampo was willing to listen to farmers before starting his own research project.

> **Kampo:** … back then I thought that rice should be like this, but now I'm thinking more of: I have to ask the farmer. They want different things.

Despite her recognition of the need to communicate with the lay public, as well as consider the needs of the lay public, Julia represents a unique case amongst the participants in that she shows qualities of Type 1, Type 2, and Type 3 scientists. For instance, her previous statements on science communication indicate that she does not believe that it is the scientists' job to communicate what they do. This makes her a Tight Boundaries, or Type 1 scientist. However, Julia is also a Type 2 scientist in that she is willing to accommodate changes in her research in order to receive funding. She sees hypocrisy in having to package one's research work, but it is a job that must be done.

> **Julia:** So one thing that I think ... we should realize is that our funding comes ... from government money largely and therefore we do have a social responsibility. It's just that learning how to package is – which is why, as I said, there's a limit as to what type of hypocrisy you can push eh. I will – this is for the poor, yeah, so give me 1 billion from the poor, so I can do my science because I am curious – right?

Later, Julia exhibits Type 3 tendencies as she talks about social obligations – all of which she says against the context of her clear views of the responsibilities of scientists, not only to their research, but to people as well.

> **Julia:** ... I think that honesty, you have to make sure that your data will be reliable ... You have to be relevant in the sense that you have to find your ... place in ... society and you have to ... determine what type of contribution you can make. You also have to be able to give a point of view that will clarify a murky issue so that ... the population you are trying to serve is not disadvantaged by false information.

Despite this unique case, the group of 20 participants is fully aware of its obligations to communicate, and to varying degrees. It is open to serving the needs of the lay public without compromising its identity as provider of trustworthy knowledge.

2. It is difficult to discern the boundaries that scientists set between themselves and knowledge brokers because they want to change knowledge brokers, or simply want to carry out science communication on their own.

Many of the participants talked about the role of science communicators and social scientists in the course of their interviews. Some of the participants, such as Marina and Nadia, believed that science communicators had a great task ahead of them because they needed to build bridges between “the hard and soft sciences.” The boundaries between scientists and social scientists, as well as between scientists and science communicators, were not as well defined when the adopted Lam (2010) framework was used. This was due to the fact that scientists wanted to carry out science communication on their own, or wanted to change social scientists and science communicators so that both types of professionals behaved like scientists as well.

Participants such as Benigno, Flora, Hipolito, Isabel, Nadia, Pedro, Quirino, Rita, Sarah, and Tanya believed that scientists needed to be directly involved in science communication – or to at least try to communicate. They believed that their knowledge of and proximity to science also made them the best mouthpieces for their fields. As the participants mentioned previously, scientists had the “hands-on experience” (Nadia) and “knowledge” (Flora and Isabel) necessary to communicate with the lay public. Pedro believed that it was preferable for scientists rather than non-scientists to communicate with the public

> **Pedro:** I think there's some people *[sic]* who are naturally good at that, um – who might not necessarily be good at doing the hard core research, we have that. Nonetheless rather than have a – someone with completely no scientific background translate the work and probably mistranslate something – it's better that someone who's sort of in the middle to do that translation for you. So I think – there are people who are naturally good at that and they should be – um, there's a place for them in the scientific scheme of things.

Only he among the twenty participants mentioned having a scientist who could communicate but not be good at research; the rest of the participants stressed that good researchers often did not know how to communicate their work well.

It is this willingness, and sometimes outright insistence, of the scientists to communicate that made the Lam (2010) framework difficult to impose and use as an exploratory lens. While the scientists were hybrid communicators when they considered boundaries between themselves and the lay public, the researchers were not drawing boundaries as clearly between themselves and knowledge brokers. Moreover, the participants often wanted the communication professionals to change their behaviors, even as the participants agreed that they sometimes needed knowledge brokers to help them communicate their research.

Only Eva, Glenda, Kampo, Lapid, Marina, Ofelia, Sarah, and Tanya addressed the subject of the mass media in greater detail. All of these participants expressed their frustration with the mass media. As mentioned in previous sections, they felt that the media too often portrayed science in a negative light (Kampo). Media personnel needed a more solid science background in order to communicate the subject matter effectively (Eva and Glenda). The participants also felt that they had a duty to correct errors they perceived were being propagated in the media (Eva, Marina, Ofelia, and Sarah) or to provide their own message to counteract the sensational and often entertainment-focused mass media (Marina and Tanya).

The participants also proposed their own solutions to what they saw as the problem of the mass media. Glenda believed that both the mass media and scientists needed training in science communication, but also believed that the media had to be corrected and changed in order to improve science communication; as she mentioned earlier, scientists could change people, and society would think scientifically. This one-way distribution of power and knowledge, and Glenda's need to deal directly with people, makes it difficult to classify her using Lam's (2010) scheme.

Lapid believed that communicating in the mass media, and before peer review, meant that researchers had a "hidden agenda". His views are consistent with Type 1 scientists who want to maintain tight boundaries between science in the media. However, in a later statement, Lapid stated that science communication in the mass media is only as good as the research that scientists produce. In summary, Lapid believed in peer review, but recognized that the mass media can still be used to communicate scientific knowledge. As with Glenda, it is difficult to classify Lapid under the Lam (2010) boundary negotiations scheme.

Sarah also voiced her frustration with the mass media because she felt that media presented the wrong information and inappropriately edited scientists, and she therefore believed that she needed to communicate directly to the lay public. For instance, she shared her experiences with the media when she wrote a science-based book for the masses:

> **Sarah**: … and then they said, you will not be involved in the writing of the book already because this will be for the [masses]. No, I said. We would like to be part of it because sometimes you will make use of words that do not mean the same. We agree that sometimes we don't have the word to be able to reach the masses. But we work together to make the book. We don't want misinterpretation.

Her statements regarding mass media are consistent with the Type 1 scientist who wants tight boundaries set between science and the mass media; however, her willingness to work on the condition of not being edited may also classify her as a Type 3 scientist, who is secure in her role as a researcher and is committed to science.

Ofelia believed that it was part of the job of scientists to correct errors in the media, and she showed no indication of role tensions in doing so. However, she also admitted to using the mass media to know what questions to ask in her own research.

> **Ofelia:** … the first thing that I do when I get to work is not to read my textbook. But it's to go and sit in the coffee room and get [the daily newspaper]. Because I need to know what are the socially relevant issues. At least to skim through the material and then there are some science topics, there are also science there, others are non-science topics – but I need to have a feel of the questions that society is asking now. And therefore when I do ask my own questions, many of which are sciences then this will have a relevant … what I've read prior to the science books ... would have … a bearing in the way we formulate … the questions.

Ofelia's willingness to listen to the public through the mass media suggests that she is a Type 3 Communicating Hybrid, who is committed to the norms of science and is willing to work with the mass media. She is also willing to alter her research program to fit external demands – but she is secure in her role as a scientist. This characteristic makes her a Type 3 as well as a Type 4 scientist, as she embodies elements of both. As with Lapid and Sarah, Ofelia cannot be definitively classified under the Lam (2010) scheme.

Participants such as Alberto, Carlos, Eva, Julia, Kampo, Marina, Ofelia, and Tanya also discussed the role that science communicators played. In this case, the participants were Type 3 Communicating Hybrids: they were willing to work with science communicators, and the participants were still fully aware of their roles as providers of knowledge and information. They also wanted science communicators to have certain characteristics, such as a good science background (Eva) or a working knowledge of science (Marina). However, the participants did not talk about altering their research programs to accommodate feedback from science communication. Like the participants who spoke about the mass media, these participants believed that scientists simply needed to provide information that science communicators could repackage for the lay public. This orientation can therefore classify the participants as Type 1 researchers, where researchers draw well-defined boundaries between their work and those of science communicators. However, the scientists did not feel threatened by science communicators, and they still expressed their social obligations to communicate research. Again, the Lam (2010) framework cannot be used to determine what researchers' boundaries are between themselves and science communicators.

Lastly, participants such as Alberto, Dina, and Kampo discussed working with social scientists. All three participants expressed that social scientists could play a key role of encouraging public acceptance of science. Indeed, Kampo claimed that social scientists should lead research projects. These three participants could be classified as Type 3 Communicating Hybrids: they want to expand their boundaries, work with social scientists, and yet are committed to the norms of science. However, these three participants, along with many of the other participants, desired that social scientists behave like scientists. They wanted to see objectivity, the scientific method, and other traditions, norms, and values of science in the social sciences. This finding, again, makes a definitive classification using the Lam (2010) scheme difficult.

Discussion of results from inductive analysis.

This section of the dissertation addresses the final research question: What other aspects of research, though not covered by the conceptual frameworks, can be valuable for future research? In order to answer this question, the researcher conducted an inductive analysis of the data. Inductive analysis involved rereading the interview transcripts for data that had not been coded or did not fall into the conceptual and theoretical frameworks used in deductive analysis. As the researcher read through these parts of the interview transcripts, she searched for frames of analysis: these were data that appeared significant, were repeated through the rest of the interviews, or presented intriguing avenues for future research. The researcher found that the participants' critique of the social sciences, their discourse on their families, as well as their reactions to the interview were repeated through most of the interviews and were also interesting.

The researcher then searched for semantic relationships among these frames of analysis. This search yielded the following domains: characteristics of the social sciences, family influence on career, teacher influence on career, and positive reaction to interview. These domains were used to recode the interview data, and both confirming and disconfirming data were marked as part of the domain. Each domain was analyzed, and themes were searched for between and among the domains. There were no themes that were common to all the domains, but each domain was dominated by a major theme. These major themes are presented as generalizations in this subsection, and are substantiated by quotes from the data and a discussion of these quotes within their respective contexts.

What other aspects of research, though not covered by the conceptual frameworks, can be valuable for future research?

The social sciences contribute to the knowledge base, but they must employ the rigor of the bench sciences before they can be considered scientific.

The scientists believed that the social sciences were limited in their ability to truly understand what it was they were studying. Alberto, Carlos, Julia, Kampo, Ofelia, Pedro, and Tanya acknowledged that this limitation was inherent in what social scientists studied.

> **Pedro:** Um, so to a large extent, I think a lot of these are obviously behavioral in nature, and it's a lot harder to pin down human behavior. As compared with the natural world, that's where the difference lies. It's not so much the – you know it's not the people … it's inherent in what they're studying.

Kampo also compared his perceptions to those of social scientists. He also acknowledged that the natural sciences were very simple in their worldviews.

> **Kampo**: You're studying holistic eh – you address this, you address that. We want simple, just give me one, we will do it. It's not – eh to them, it's not yes or no. To us it's just yes or no. There's 'but'.

Julia agreed that the social sciences dealt with a much larger number of possible outcomes compared with the natural sciences. She linked this number of outcomes to the reliability of the natural sciences compared with the social sciences.

> **Julia:** … at least in the sciences, you more or less know what types you – you can expect. You can be surprised every so often, but there is a limit as to the range of … end points that you're going to get. In the other activities I think, it's more open-ended, like if you compare, let's say, doing – actually doing science with, with let's say public consultation, the outcomes that you anticipate in the sciences are more defined and are rather more controlled because you did control the way that you're doing the experiments.

The concept of experiments was raised consistently when the participants were asked about the social sciences. For example, Rita agreed that the social sciences also had experiment-based protocols, but she believed that "the mental discipline is different." Nadia voiced her skepticism with surveys because they were very different from "wet lab" experiments.

> **Nadia**: …. you see, the perception, the perception, I said, um, what is this, really? Uh, it's like … you can't – unlike in a wet, in a wet uh experiment, you – you would really see uh, this, this is positive, negative. If it's a perception or survey, it's like uh, for me, this is personal ha, I would say that eh, I can ask just about anybody eh ... is that even true?

Rita already had experiences working with social scientists: she was taking classes in bioethics and tasked to head focus group discussions. These activities had made her even more skeptical of social sciences research in general, and qualitative methods in particular.

> **Rita:** That's why I'm having a hard time with quail … (laughter) That, this thing you're doing is quali – you're in charge of the interpretation, the translation! But here it is, these are numbers, and I can't do anything with them anymore! That's why – that's why – I have a hard time actually, doing focus group discussions – but it just goes fast

> because that's it, it's not struc – I'm not structured. So like – rapporteur – but it should be structured!

Rita's comparison of quantitative and qualitative research methods was echoed through many of the interviews. To Rita, the quantitative research methods prevalent in the bench sciences made them more objective and impossible to manipulate. Eva agreed with this statement, and went on to discuss how the natural sciences were taking on the social sciences with their own tools.

> **Eva:** Um – I think there's a really big debate about uh, social scientists and uh um the natural scientists and the physical scientists. Uh, at least in this country, very few of our social scientists have uh quantitative measurements and use quantitative data or probably modeling. So most of these um, both the nature of the - so they are always at the brunt of the, of the physical scientists or the economists even, economics, and other natural scientists, because uh, many of their, many of their discussions are really very, very descriptive and in fact, there are actually computational tools or modeling tools which could uh, test the validity or validate their conclusions. So at least in the Philippines very few if almost nil of our scientist really use computational tools. So unless you have some quantitative data and unless it can be reproduced by others, then there's always that doubt as to the validity of the experiment. And I think that's the major weakness of many of our social scientists who do not embrace the fact that there actually certain tools um, using computing systems and other uh, to, to essentially actually predict certain behaviors – and they do not use that ... So you now see a lot of physicists who are doing social science work

The pursuit of truth also dominated the interviews, whether or not the scientists mentioned the need for quantitative research. For Sarah, the difference between the social sciences and bench sciences was in the lack of verifiability of the social sciences, from the method, to the data, to the interpretation of data.

> **Sarah:** … they have some approaches which are scientific. But the interpretation is not completely scientific. That's why they're called social science eh – they – they consider values which could not be verifiable. Uh, approaches which could not be verifiable. It's free - more free (laughter) more free than the scientific method.

To Sarah, scientific work consisted in verifying phenomena that occurred repeatedly. Social scientists, according to Sarah, were working with data that could not be verified, using approaches that could not be verified, and analytical tools that could not be verified. Julia agreed with this lack of verifiability and, in the process, compared the social with the bench sciences.

> **Julia:** Yes – I think yes, uh it's a – so that – in the social sciences, the type, the range of variability that you get is – is actually very very high, to the point that you – you tend to make generalization so you tend to exclude data, or simply try to interpret one very narrow range among the entire gamut of, of – of results that you actually get. Yeah, I think – it's – it's – it's actually more reliable than the social sciences.

Julia explained her views by calling on the various norms of the bench sciences: the use of controls, defined parameters, conclusions backed up by data, and formulating causal relationships.

> **Julia**: … I think extrapolations have to be tested for them to be totally scientific ... Because causal relationships cannot – cannot simply be proven by pure correlations … largely conjecture, because I don't understand how the political scientist would be able to say that this is the cause for this … I do not understand that. Maybe I do not know about that – enough about that field to be able to categorically say, 'Sounds like a science to me.'Because what – how do you form conclusions? Uh, if you cannot control the variables? And I have not come across, at least from locally produced papers, I've not come across a social scientist, who actually defined all the parameters, that – that - that they actually used to make the conclusion, especially if the conclusion has some apparent political color.

Lapid agreed with both Julia and Sarah in their assessment of the social sciences. He believed that the conclusions drawn by social scientists were not as definitive, and that anyone could come up with their own interpretation of phenomena.

> **Lapid**: Well they're definitely different. How do you put logic in human behavior? So that's a bit tricky: you can't really relate how a

> person or how a society will think or act - it's different … analyzing things and you know, sort of historical … you can always come up, I mean, someone can always come up with different rationale, or reason for why things happen. Look at a person or an event and say, you know, [our National Hero] did this, because no one knows that when he was a child, an uncle did this. So you know, things like those, so in a sense the, I mean, if the reasoning is sort of rational, and goes straight, the explanations are usually not as definitive. So it's that - yeah, factors like that that you can't really say are the same with social scientists.

Kampo did not explicitly talk about how the social sciences were not definitive or verifiable. Instead, he praised the social sciences for being "holistic", even as he claimed that they "complicated" the lives of scientists.

> **Kampo:** Your product is not going to be applicable. If you want your things delivered to the farmer, to the intended user, you have to have the social scientist. If I want it for my own curiosity for scientific publication, for this one, get rid of the social scientist if you don't have the patience. You could not publish. (laughter).

Some of the participants were more tolerant of the ways of thinking and doing of the social sciences.

> **Dina:** It's different – how would I say it – the ways are, are different, of – evaluating assessing, because the social is – it's really all about social behavioral, and it's humanistic, isn't it? That's still science, maybe, I don't know – maybe we have to delineate the two. The social is different. But social scientists have a role to play here, for, for the hard science to be accepted especially with the controversial … we need behavioral science – *something like that*.

This tolerance for the social sciences also seemed rooted in a perception of the social sciences as a field that had adopted the tools of the bench sciences to suit its purposes. For instance, Rita considered only demography as a scientific social science because it used statistical analysis, which she considered a scientific tool. Glenda claimed that her social sciences colleagues appreciated how engineers liked to quantify things, and how social scientists were also using statistics. Marina had already claimed earlier that scientists needed to be quantitative, and she repeated it in her statement for the social sciences.

> **Marina:** … because the, social science has a quantitative aspect sometimes, too. Yes. That's like, um, well, it's mainly fields, like demog – demography, the statistics. The statistics is the one that really uh provides … the quantitative aspect of social science. And uh it's great, too – the social is great, I mean, it's interesting. And it's more difficult to control. It's not like test tube experiments that are easy or uh, the animals that are harder to control versus … the test tube experiments. But people are more difficult. It's really hard – I find it hard to control. So there are many judgment-based judgment calls that you do, that you need of course … so that science will progress, so you need judgment, you make judgment calls … but I think that's more important in social science.

Nadia's assessment of the social sciences rested on their methods, and how their mixed methods yielded more reliable data.

> **Nadia:** Rigor and depth … because if you look at some of the methodologies of social sciences, they're both qualitative and quantitative. And sometimes they – they merge the two methodologies and I think they – they come up with good uh outputs….

Isabel related her own work as a scientist to the work that social scientists did.

> **Isabel:** Yes, because they have – they have, what do you call that, a scientific method that they use.

Flora, who worked in both the mathematical and social sciences, first began her discourse on the social sciences by focusing on quantitative-based research. She believed that the "growing effort" to make the social sciences more scientific was due to their "increasing dependence on quantification."

> **Flora:** To provide support for their theories. Yes, not so scientific as uh hard science in the sense that … the motivation is … I have personal insight that just came in.

Flora then changed her statement and began to talk about social constructivism, which she had also studied as part of her duties as a math educator.

> **Flora:** … let me continue to clarify … I guess my being a social constructivist is….the source of this dilemma now … Because in hard science, you see, we – we talk about um, theories that may not have any social context, right? Ok, but then, I just – it – the thought just came to mind right now that there is no social context because we try – we try to detach it from its origins.

Flora's views on social contexts and how they relate to theories were not mentioned in the rest of the interviews. For Lapid, the tools of the social sciences were simply different because what they studied was full of uncertainties to begin with, and mathematics was impossible to use.

> **Lapid:** … there's usually no unique answer to all questions, so it's more difficult. But to the extent that they have rules of doing it. The rules don't have to be quantitative - you know - no I can't imagine it being more mathematical…But there's actually a way of proceeding with this sort of way of this sort of practice that can largely be scientific … Yeah - I've worked with them. But I think it would be a mistake for scientists to apply their rules to social science.

To Pedro, the social sciences were simply another branch of knowledge that had its own challenges.

> **Pedro:** I think it's essential that we respect the difficulties that these people face. If there was a better way of doing things for example in sociology or linguistics and whatever – if there was a way through it with more rigor than people would account – as long as there is progress I think that's perfectly fine and the challenge is – in other words, I don't think I could do it better than they could, so....

On the whole, the participants believed in one of several things: the social sciences still lacked the tools, and therefore the reliability of the bench sciences; the social sciences were already quantitative enough; or the social sciences stood on their own and had their own merits as a field of knowledge. What was common in the interviews, however, was a comparison of their field with the social sciences – and sometimes, an imposition of rules on the social sciences. With the exception of Lapid and Kampo, and, to some extent, Flora, the participants placed conditions on what they considered as valid fields of study, and using the tenets of the bench sciences.

For example, Eva proposed that social scientists learn to use computational models to analyze social sciences data. In line with this, Ofelia recognized that interviews were needed in the social sciences, but she had her own opinion on how they should be carried out and analyzed.

> **Ofelia**: So the data that would be generated must be qualified. This means that this data was generated using experimentation and are repeatable. This information was derived using a statistical analysis of the interviews of however many number of people. So there's a scope – that's for all methods, and that's for all data. You know when you present some data, you need to provide the scope and limitation of the particular data. So I generated this data, whether it's hard or soft science, you need to qualify in order for you reader or your stakeholder to be able to understand the significance of – of that particular data.

Carlos even claimed that the social sciences could be considered science only if they applied the scientific method, and if their work was based on the sciences.

> **Carlos:** Uh, if they apply scientific method to study certain things, uh, then that's science also, I think. That could qualify as science. I think the most debatable there would be economics … there are certain models in economics that certainly have worked … and that's because of, uh, of scientific work that has been done. Uh, just look at the economists who have won Nobel prizes – game theory, etc. these things work … because they're based on uh, based on science. So yeah, I think they're scientific if you ask me.

This same condition was applied by Tanya in her own statement about the social sciences.

> **Tanya:** Um, if – if the um the methods used um – yeah, they want to be um, they are related to political and social sciences, etc. if the methods that are used to uh, uh to produce results, findings and results, data and results are uh, similar to the ones that are used in the hard sciences, yeah, they – they could be.

In summary, while the participants believed that social scientists could assist them with social acceptability of the bench sciences, the participants still wanted social scientists to adopt the methods of the bench sciences. Such a view is reported in the literature (for instance, in Eigenbrode et al., 2007), and could be ascribed to the participants' worldview and science culture, which predominates many of their views. The participants' belief in an objective, measurable reality clashes with the work of social scientists, which deals with multiple variables, approximations, and a different definition of objectivity.

Family and teachers, along with economics, play a great part in the choice of science career.

The “ice breaker” questions in the interview were meant to ease participants into thinking about their practice. Their responses, however, also provided personal stories that gave information on how they had been socialized into the scientific discipline. For example, Benigno, Flora, Kampo, and Marina had been influenced, in one way or another, by their fathers. Their fathers had taught them science or mathematics, or were in the research arena as well. Kampo, in particular, referred to his father as his mentor.

> **Kampo:** I have my mentor – my mentor really is my father. Yeah, he's an agriculture engineer, he is the one encouraging me to do this, and he's training me … no one mentored me, although I have a science teacher who was a … scientist … but it’s my father … encouraging, because when we debate, we talk, we talk – we talk about everything,

> we talk about scien – statistics, we end up [in] statistics because he's a statistician, too.

The rest of the participants also shared their personal journeys in science. Julia and Rita had each been influenced by their mothers, both of whom had pushed them into science because of economic reasons. Some of the participants were also influenced by a mixture of family and economics. Carlos and Sarah both felt that their families had encouraged them to think and live liberally, which also prepared them for the critical thinking that came with research. Dina and Quirino each had uncles who were in the same field as they, which likewise made them pursue research and have a model to base their behavior on. Glenda and Hipolito both came from poor families, and although they each wanted to work in non-science related fields, they had to pursue the sciences to make a better living.

School was also an important factor in influencing the participants to pursue the sciences. Isabel, Ofelia, and Pedro were all influenced by school and how it made them see the logic of science. Ofelia noted how her mentors had helped her on her way to becoming a scientist.

> **Ofelia:** … I've found personal satisfaction there, I've had good mentors, I have been very uh fortunate to find good educators all along the way, um who are willing to answer and have the patience to answer my questions when I had them, um, who encouraged me to work hard, um, and also who um, provided the path um of my own choice, but they guided me from Point A to Point B until I reached Point C.

Having mentors and influential teachers was instrumental in leading Alberto, Eva, Lapid, Nadia, and Tanya to a career in science. For Alberto, it was a series of good science teachers from elementary to high school that influenced him to pursue the sciences. Eva found that she had a natural aptitude for the natural and physical sciences, but also found that she wanted to pursue a career in any subject as long as the teacher was also good.

> **Eva:** I was a relatively good student in math – and when the teacher was also very good in physics, I also wanted to go into physics. When my high school teacher was very good in economics I also wanted to go into economics.

Nadia and Tanya, who both had a background in chemistry, also mentioned their chemistry teachers.

> **Tanya:** You know, it's the first time that we were taught chemistry, and my chemistry teacher then was very good. We had a good book, and I performed well, and she recognized that, and um, immediately I um, I liked the subject. I – I won't say that it was easy but there was some kind of … exactness about it … quantitative, and I like that, too.

> **Nadia:** Yes. High school teacher - 3rd year - 3rd year, it was really chem … she was really strict, but she made our laboratory experiments in a way that we really enjoyed them – but for me, it was magic….

As stated previously in this discussion, the participants were aware of how different school science was from how science was being practiced in the real world. Nevertheless, parents, family, teachers, and economics still played a great role in setting them on their path to the sciences. The participants' personal accounts of how they had been socialized into science has been tackled and parsed in the literature as well. Role models, in particular, have been studied, especially in the context of gender issues in science (Zeldin & Pajares, 2000). In a more recent study, Jones, Taylor, and Forrester (2010) carried out semi-structured interviews with scientists and engineers, and found that teachers, professors, museums, and the outdoors contributed to a love of learning and knowledge.

The researchers' reactions to the interview process can also be attributed to the science culture.

When the feedback section of the interview was first formulated, it was meant to be a way for participants to provide their own perspective of how the interview could be improved. Julia and Lapid actually provided additional questions that could be used to improve future interview protocols. The participants, had reactions to the interview that could be attributed to their science culture. For instance, Benigno, Rita, Julia, Isabel, Lapid, Marina, Ofelia, Pedro, and Tanya all wondered what the research objective was and, in particular, what the aim, endpoint, or hypotheses were. Julia was also uneasy that statistical analysis would not be done on the interviews.

> **Julia:** Well, I don't know what endpoint you want to reach. You know me, I'm a scientist, I want to look at the endpoints eh. Like – what – what – what is the question you're trying to ask, and what is the thing you're trying to address? Is it – is it a cultural difference between Filipino scientists and American scientists? Or – is it – is it going to be … what drives you, or what makes you think, sort of thing? So I'm not quite clear about that.

Glenda complimented the interview style and process. She believed that it was "scientific" because it felt "logical." Ofelia, like the rest of the participants, was also critical about the research, but was curious about the data that it would generate. She had already said early on that she was very much a utilitarian and could not pass judgment on the study until it had made a difference, a demand that could be traced to her perceived culture of science, where work needed to have an impact.

> **Ofelia:** You know – I always tell them, if there's useful data, there's not useful data. So it's only being a good study if the data generated will create an impact.

Dina, Eva, Glenda, Marina, Nadia, Sarah, and Tanya requested the researcher to return to the Philippines and continue her work. Eva, in particular, believed that the researcher's background in molecular biology made her a better science communicator. Even in giving feedback, the researchers were calling on their values and norms to make what they believed to be a good assessment of the researcher's current and future work.

The process of interviewing the researchers benefited them in various ways.

Alberto, Dina, Eva, Flora, Glenda, Hipolito, Kampo, Marina, and Tanya actually complimented the researcher on the interview, and had admitted that it benefited them in various ways. Pedro even asked for a copy of the dissertation because he wanted to see how scientists thought and reasoned; he believed that there was very low science literacy in the lay public, and scientists were mandated.

Dina said that the interview made her realize that she had her own beliefs as a scientist, and talking about them was a welcome change.

> **Dina:** Well it was very good, because you know, these are the things that we want to talk about, other than what we talk about in terms of results, or in terms of conflicts on differences on the procedures that we use. Be – because the dimension – it's different eh. And when you work, you do not work exclusively as a scientist doing this. You consider a lot of things even when you draw up your plans or research agenda, it's a culture … as you said, beliefs.

Flora was working in both mathematics and education, and the interview, she believed, had clarified the philosophies that she held in the fields that she worked in.

> **Flora:** Well, I guess the interview made me really think seriously about what I think of my work, and how I think I could best do it. Ok? So I guess it was really a very fruitful experience … having been given the opportunity to rec – to recollect my thoughts, to find out ok, what I think of math, ok, and what I think of uh my responsibilities, ok, as a mathematics teacher, mathematics educator, and researcher, and I guess these uh, ideas should really be part and parcel of my philosophy.

Combined Frameworks for Philippine Participants

This subsection of the Discussion section will discuss the findings from the Philippine phase of the study. Each subsection will present a summary of the findings, followed by a discussion: the first subsection will discuss findings in a combined framework of worldviews, culture, and communication models; and the second subsection will discuss findings in a combined framework of culture-as-toolbox and boundary setting.

A combined framework of worldviews, culture, and communication models.

A deductive analysis of the interviews and field notes from the Philippine phase suggested that the participants valued honesty, openness, passion, love for knowledge, mental capacity, and the societal impact of their work. These values gave rise to norms of science, which included objectivity, collaboration, hard work, mentoring, updating one's knowledge base, creativity, systematic work, research productivity, and publishing or communicating. The participants disapproved of overconcluding or overinterpreting data, dishonesty, secrecy, laziness, lack of objectivity, and copying other participants' work. These behaviors and characteristics, the participants believed, would halt progress in the field and even place lives at risk. The participants had been socialized through years of school and training, but they also recognized that the science that they had learned in school was different from how it was truly practiced.

The participants also work in a culture that often discourages good research behavior. They described traits such as sensitivity and lack of assertiveness, politics, colonial mentality, crab mentality, and lack of commitment to long term work as traits that inhibited success in science. Lack of funding exacerbated the cultural traits that made science difficult to practice in the Philippines. However, the participants also believed that Filipino traits such as resourcefulness, a strong family background, faith, and allowing females to advance in their careers could make Filipinos good researchers. They also believed that Ph.D. training abroad erased any poor Filipino cultural traits. The participants also admitted to being religious but many believed that it was a personal choice or decision and did not affect their science.

The participants also practiced and espoused a post-positivist worldview, but still believed in the ideals of positivism.

Much research has already been conducted on what scientists believe to be the norms and values of science (Berk et al., 2000; Hermanowicz, 2006). Not all the participants agree with the old Mertonian (1942) norms of communalism, universalism, disinterestedness, and organized skepticism, and the same can be said of the participants in this phase of the study. This might be due to the fact that the participants acknowledged that completed objectivity or disinterestedness was not possible. This might also be due to the fact that the participants are unable to practice some of the norms while operating in the Philippine research arena. Communalism, or knowledge and information sharing, is difficult; organized skepticism, though ideal, is hampered by cultural habits; and the universalism of science therefore no longer applies.

The differences between science in the real world and science in the classroom have also been tackled in the science education literature, and the observations that participants provided in this set of interviews are consistent with the findings of other studies (Harwood et al., 2002; Monhardt et al., 1999; Schwartz & Lederman, 2008; Wong & Hodson, 2009; Zeldin & Pajares, 2000). In school, science is often seen as absolute, with all the answers, and where scientists all agree with each other on their findings. It is no small wonder, therefore, that non-scientists find it unsettling when scientists do not show agreement on issues such as climate change, global warming, or genetically modified crops.

From the progression of the participants' perceptions of science, it appears that school science was largely positivist: facts were absolutely known and science had all the answers. In the words of Nadia and Kampo, science was like “magic”. But as the participants moved forward in their training, science became post-positivist: the participants lost their naiveté about their respective fields, found that science could not answer all questions, and discovered how interpretations could differ from person to person.

In practice, the participants were post-positivist: they believed in triangulation of methods, consulting with peers to obtain a better perception of their data, changing knowledge, and personal biases getting in the way of their work. However, the participants still held on to several ideals of positivism: the objectivity of an individual researcher, a measurable world with patterns, and to some extent, the absolute nature of scientific facts.

This dual worldview needs to be understood in the context of two cultures: the culture that researchers hold amongst themselves, and the culture that surrounds the researchers. Based on their answers to the interviews, as well as the field notes taken before and after their interviews, the participants appear to be experiencing a clash between their scientific culture and the culture at large.

Religion might appear to be an issue for some of the participants, but for many of them, religion is either a personal choice that is distinct from one's science career, or matches with the values of the scientific culture. It is this match of values that makes them comfortable not only to admit that they are religious, but to remain religious as well even when they belong to a field that is traditionally distinct and isolated from religion. The participants in this phase of the study are therefore able to delineate their religious lives and scientific lives without difficulty. However, there are other Filipino cultural traits that they mentioned which run contrary to the norms and values of science.

First, the lack of assertiveness of Filipinos is a sign of lack of critical thinking in other cultures, as Carlos said. In the science culture, it could be a sign of one’s lack of commitment to the norms and values of science, which place a premium on critical thought, mental capacity, and creativity.

Sensitivity to criticism prevents some researchers from publishing their work, a trait which also clashes with the openness of science. Moreover, sensitivity to criticism and politics in science are both associated with a focus on personality, as well as taking issues personally. The science culture, on the other hand, focuses on expertise, mental capacity, and objectivity. Thus, being oversensitive to criticism and relying on politics to move forward in science both clash with the science culture because they run contrary to the values espoused by participants. This clash can inhibit scientific work at the beginning of one's science career, where a researcher is taught to publish and share their findings; and in the middle of one's career, where a scientist must look for funding, publish work, and do research.

Crab mentality also clashes with the values of openness and love of knowledge. Openness and love of knowledge should lead to sharing of one's findings, collaboration with other scientists, and publishing one's work. Sharing one's findings, collaboration with other scientists, and publishing one's work, the participants claimed, would lead to progress in research. With crab mentality forcing competition amongst researchers, researchers hide their data and likewise keep the entire research arena from progressing as a whole.

The *ningas cogon* mentality clashes with the value of passion in science. Passion is a value that leads to the norm of hard work. This value of passion might be linked to another value, that of patience. Because researchers have no patience to deal with a long-term project, they often baulk at having to participate in any project that requires too much time commitment. Hence, they start with a great commitment and promises of work, only to drop out from the project after they lose their initial enthusiasm. Without a long-term plan, no progress occurs in science.

All these cultural traits stand in the way of both scientific work and science communication. They clash with the values of passion, honesty, patience, and love for knowledge; consequently, they contradict the norms of objectivity, collaboration, productivity, and publishing. In addition to these cultural traits, lack of funding makes the problems of poor scientific research and communication even worse.

The effects of problems in funding have also been documented in the literature (Lam, 2010; Varma, 2000). In particular, Anderson et al. (2007) conducted focus group discussions with 51 scientists, and found that secrecy and withholding information were common when scientists perceived high levels of competition. Moreover, competition led to: strategic game-playing, decline of free and open sharing of information and methods, sabotage of others' ability to use one's work, interference with peer-review processes, deformation of relationships, and careless or questionable research conduct (Anderson et al., 2007).

The findings of Anderson et al. (2007) are consistent with the results of this phase of the research. However, it appears that research difficulties in the Philippine situation are not only due to funding issues, but to cultural traits as well. Moreover, the norms and values of the science culture clash with the poor research behavior engendered by competition and funding. It comes as no surprise, therefore, that participants are asking for more funding, because it appears that the effects of poor funding clash with the values that they hold.

When the surrounding culture, science culture, and funding situation are taken together, it seems that a dual worldview is needed in order to deal with the clashes that ensue. The participants in this study believed that science could measure an objective reality with close approximation, and through the use of careful experimentation. They believed that scientific objectivity was not only possible, but that it could help them carry out their experiments and interpret their results better. This objectivity came in the form of personal objectivity and validation of results by one's peers. The participants believed that valid knowledge was that which had been supported by careful scientific methods, reproduced by several laboratories, and confirmed by different approaches. Despite the strict objectivity, the participants did not discount the effects that culture, training, and theory had on a researcher's work.

There appears to be a dual nature of scientific worldviews: there is a science that *should be* and a science that *is.* The participants in this study believe that an ideal science would be one where objectivity is possible, where reality is objective and measurable, and where researchers should not be influenced by outside forces – a positivist worldview. Such a positivist worldview can be valuable when researchers have to deal with lack of objectivity in their environment; for instance, due to politics in science, or sensitivity to criticism by their peers. The researchers are trying to enforce the science that *should be*.

However, the participants in this study also acknowledged that science operates in the real world: science is limited, researchers cannot always be completely objective, reality can be approximated through a triangulation of methods, and scientific work is influenced by outside forces – a post-positivist worldview. In this case, the researchers are dealing with the science that *is.*

When these two worldviews are taken together, it appears that the researchers are practicing a form of double gatekeeping. They seem to enforce the strict rules of positivism on their work, all while providing themselves a safety net to account for their limitations. This double gatekeeping also plays into what the researchers believe is effective science communication.

In order to understand how the worldviews influence science communication beliefs, the frameworks of worldviews by Guba and Lincoln (1994) and science communication programs by Trench (2008) must be combined. When used together, these frameworks link the researchers' worldviews with their opinions on how science communication should be conducted. In this phase of the research, it appears that belief in the dissemination model of science communication is consistent with a mixed positivist/post-positivist worldview of science, as well as the science culture that the researchers believed in.

According to the participants, science communication must convey accurate scientific information to an audience that needs this information to lead better lives. Those carrying out science communication must deliver scientific facts, speak objectively about science, and have working knowledge of science. Such conditions are reminiscent of the worldviews that the researchers hold and the culture that they work in.

First, the researchers believe that science communication can help society change for the better. This perceived aim is consistent with the post-positivist worldview, where researchers acknowledge their debt to society and that knowledge must be shared. This is also consistent with their cultural value of openness, and their cultural norm of publishing, which dictate that they must share their results.

Second, the researchers believe that emotions should be left out of communication, and science communication must be carried out objectively. These qualifications are consistent with the positivist worldview, where researchers believe that complete objectivity is possible.

Third, the researchers want science communicators to have a good background in science. The researchers in this study value mental capacity and knowledge of the field, which they feel gives rise to good science; they expect professionals to be trained in science and have a good knowledge of science, which they feel give rise to good scientific practice. They have transferred this philosophy to their view of good communication, where they feel that science communicators must have as much science training as possible in order to talk about it.

Fourth, and most important, the researchers believe that stating the facts will lead to better science communication. This reliance on the facts is again consistent with the positivist view of science, where the researchers believe that the facts speak for themselves and should be accepted because they come from science, the trusted source of information. However, the researchers themselves acknowledge that knowledge is still changing, and what are facts today might not be correct tomorrow. Nevertheless, the researchers insist that science communication must present the facts, and the public must listen to the facts, as though the facts were already set in stone.

In short, the researchers carry out science communication under the demands of the science that *is* but expect the lay public to accept the assumptions of the science that *should be.* This united view of worldviews and beliefs in science communication can be found in the literature. For instance, Coll et al. (2009) discuss the public and private faces of science. Researchers often present a side of themselves that makes them appear to agree with each other in order to present a united front to the lay public (Coll et al., 2009). Researchers do so because they do not want to break away from the group; they do not speak about contrary findings lest they jeopardize the united face of science (Coll et al., 2009).

What the findings in this research show, however, is that the researchers might actually be presenting a united front in order to deal with the clash of their values with those that are held by the world at large. The researchers present a public face of science that is objective, absolute, and a bastion of knowledge. This public face exists as a defense in order to deal with the lack of objectivity, sensationalism, and lack of knowledge in the lay public. This public face also allows them to carry out communication in the best way that they know possible: by providing information to non-researchers, whom they believe need information in order to lead better lives. This matches the dissemination model as characterized by Trench (2008). The dissemination model is one that operates on absolute facts, where science is the source of knowledge and the public must accept the knowledge that science provides. Belief in the dissemination model, therefore, is not only consistent with the worldviews that the scientists hold, but is a way for them to deal with a lay public that does not share their culture.

Privately, however, the researchers have set out a safety net for themselves by practicing post-positivist science. In this private world of science, knowledge is not absolute, researchers are not completely objective, and researchers must share their knowledge with each other so that they can validate their findings. Because knowledge is not yet absolute, research must continue and researchers must keep working to find the truth. Because researchers are not completely objective, they must rely on their peers and carry out even more experiments to validate their findings. The post-positivist face of science is also a place where science must continue to work. The private face of science, therefore, is also encouragement for researchers to keep on working despite the clash of their values with those of the outside world. The private face of science is even an order for researchers to behave well, to continue being honest, and to continue sharing their data despite the difficulties that they are undergoing.

To conclude this section of the discussion, it appears that the participants' positivist/post-positivist view of science, as well as their culture, all contribute to how they regard the task of science communication. Thus, the combined Guba and Lincoln (1994) and Trench (2008) frameworks is valuable, not only in finding out what the worldviews and cultures of scientists are, and not only in finding out what science communication model they believe in. The combined framework can contribute to a deeper understanding of: (a) why the researchers' worldviews are structured in a certain way and (b) why they believe in a certain model of science communication.

For a deeper understanding of their role in science communication, the participants must be understood in terms of what they perceive to be the new culture of science, what they perceive to be their tools in dealing with this culture, and how they define their role in science communication relative to other participants in the science communication process. To carry this out, a combined framework must be used to explore their culture and the boundaries that they set.

A combined framework of culture-as-toolbox and boundary setting.

A deductive analysis of the interviews and field notes from the Philippine phase suggested that the participants perceived a change in the current science research arena. They believed that scientists needed to take on different duties outside the laboratory. Such duties required them to communicate with the lay public and collaborate with participants from other fields. The new culture of science required them to use tools from science in order to deal with the lay public. The participants also needed to work with various knowledge brokers, but their relationships with these knowledge brokers varied depending on the knowledge brokers.

In this subsection of the discussion, Swidler's culture-as-toolbox model (1986) is combined with Lam's boundary-setting framework (2010) in order to gain a deeper understanding of the science communication culture, and what the participants believe their role is in science communication.

According to the participants, the way that science communication was being conducted in the Philippines clashed with the traditions of science. The participants, however, believed that they were equipped with tools that allowed them to cope with the change and the clashes. The data suggests that the participants believed that these tools had been given to them by their science training. These tools include the values of honesty, the love of knowledge, and openness; and the norms of objectivity, research productivity, and publishing. Nevertheless, the participants believed that they needed more tools to improve science communication. They needed social scientists, science communicators, and communication training.

The players in science communication, according to a majority of the participants, included the participants themselves, the lay public, and knowledge brokers. The participants' attitudes to these different players were likewise different. Each player had a role in the new science culture, and each role can be understood when the boundaries between them and researchers are investigated further.

When dealing with the public, a majority of the participants were Communicating Hybrids. They were aware of their social obligations to communicate, but they were aware of their obligations as scientists as well and did not experience any role identity tension. In talking about their role as communicators for the lay public, the participants were also using their science culture, where they had obligations to serve society. This sense of serving the needs of the public, however, was not limited to scientific facts. The participants wanted the public to appreciate science and think like scientists, and science communication could help them. According to some of the participants, the public needed to think critically and logically, both of which are characteristic of the culture of science.

Science communication, therefore, was a way for the public to be armed with the tools of science as well.

However, the boundaries that participants set between themselves and knowledge brokers, such as science communicators and social scientists, were not as definitive. For one, the participants wanted to change knowledge brokers' characteristics and behavior. The participants believed that the tools that their science training provided should also be used by other scholars, such as social scientists, in order to move their field forward. The participants also believed that science communication must be done by people who think and act like scientists, using science-based messages, and with constant consultation with scientists. In some cases, the participants also wanted to carry out science communication on their own.

The researchers also criticized the work of knowledge brokers, and in particular, the mass media. Their criticism provides even more insight into the science communication culture in the Philippines. According to the participants, media played on people's emotions, did not use facts, or did not go straight to the point. They also criticized science communicators who practiced their craft poorly because these science communicators did not have science training.

The participants' opinion of what constitutes flawed science communication can be traced to their belief in the tools of science. Using the Swidler model (1986) of culture-as-toolbox, these tools allowed scientists to deal with the increasing demand for them to communicate their findings. According to the participants, their role was to provide information that would allow people to behave the way that researchers did, think the way that researchers did, and change the world at large.

The participants' critique of the mass media can also be traced to the influence of their science culture. A media playing on emotions runs contrary to the norm of objectivity in science. Lack of facts runs contrary to the values of honesty and love of knowledge. Not going straight to the point runs contrary not only to the values and norms of science, but to the participants' conception of an objective reality, as well as a scientific method that yields black-and-white answers. Lack of science training runs contrary to the value of love of knowledge.

Moreover, many of the scientists believed that they needed to be consulted in science communication. This insistence on direct or almost direct involvement could stem from the love of knowledge, a value in science that allows scientists to lend great importance to the facts in all the things that they do. This insistence on involvement in science communication also arises from the dissemination model that scientists espouse, where scientific knowledge is held in high regard. This dissemination model, in turn, arises from the positivist worldview that scientists advocate: they believe that they can measure an objective reality, and that they have the expertise that sets them apart from the lay public.

Using the Lam (2010) scheme to categorize the boundaries between researchers and knowledge brokers might be difficult due to several factors. For instance, the Lam (2010) scheme was originally formulated to classify the boundaries that researchers draw between themselves and industry. The relationship between researchers and industry is different from the relationship between researchers and knowledge brokers. Researchers respond to the needs and demands of industry, and the interaction can be seen as a large group (science) in opposition to or cooperation with another large group (industry). This relationship is more similar to that between researchers (a large group representing science) and the lay public (a large group representing society). Another similarity is that the researchers can carry out their work for the benefit of industry and the lay public – but the researchers do not carry out their work for the benefit of knowledge brokers.

Nevertheless, the combined schemes presented by Swidler (1986) and Lam (2010) provide a richer view of the current science culture. Without the Lam (2010) framework, the Swidler (1986) framework might make it appear that the only players in the science communication arena are the researchers themselves. Without the Swidler (1986) framework, the Lam (2010) framework will have only a description of boundaries without a deeper understanding as to why these boundaries even exist.

Using Swidler's (1986) framework, the science communication culture appears to be flawed, but researchers have tools to deal with the clashes and changes brought about by the need to communicate with the lay public. Using Lam's (2010) framework, the participants appear to be the providers of knowledge for the lay public, and science appears to provide the tools that will help society and knowledge brokers alike move forward. When these findings are taken together, a more complete portrait of the current science culture is formed: researchers have tools to help them deal with the new norm of science communication; these tools make them the source of knowledge for communication, and it is these knowledge and tools that set them apart from the other members of the science communication culture.

Whether they considered science communication as a skill or talent; whether they believed they could carry out science communication on their own or needed assistance from knowledge brokers, the participants in this study were well aware of the need to communicate their findings to the lay public. Their training as scientists made them think and believe in certain ways, and they critiqued science communication practices based on these culturally-rooted thoughts and beliefs. Nevertheless, their training as researchers had made them conscious of their role in society, and of their need to share their findings, both of which were tools that the participants used to deal with the current and pressing need for science communication.

Findings from the United States

In this portion of deductive analysis, the researcher read through the data and highlighted portions of participants' responses that addressed their worldviews and culture. These typologies were presented earlier in the Methods section of this document, and are detailed in Appendix G. When the data were coded using the typologies, the researcher summarized the ideas from the participants' responses under each typology. The researcher looked for overarching themes within the summaries of the typologies. These overarching themes were then used to recode the already marked data. The researcher then used these coded portions of the data to create generalizations to answer the research question and its sub-questions.

These generalizations are presented again this section, along with quotes from the data and discussions of these quotes in context.

Discussion of results from deductive analysis.

This subsection of the discussion will provide answers to the research questions of this study by presenting generalizations derived from the patterns and themes in participants' responses to the interview questions. These generalizations will be supported by a discussion and direct quotations from the data.

What are the worldviews and cultures of the participating researchers?

What is the worldview of the participating researchers?

The participants in this study were all post-positivists, except for two participants, who were positivists. In this subsection of the discussion, the views of the post-positivists will be presented first, followed by the views of the positivist participants.

The post-positivist participants believed in an objective reality that researchers could only approximate. While they believed that science was searching for truth, they also believed that what they found through their research was not completely accurate or stable.

Bethany, a molecular biologist, stated that "science is trying to understand how nature works." She also believed that as tools changed, the ability to measure reality would change. Nathaniel, and environmental scientist, agreed with Bethany as he discussed what to do with data:

> **Nathaniel:** And from there solve the problem, if, if at all, if that's possible and I guess an approximation of a solution, see if that solution jives with what you actually observed in the real world.

According to participants such as Arthur, Bethany, Larry, Patrick, and Robert, the inability to completely find or report the truth lay in the fact that scientists are human and can have different interpretations of the same data. David, a mathematician and Harold, a biophysicist, exemplified these views in their statements on objectivity.

> **David:** Yeah, be objective. But like I said, it really goes against the very nature that we have as humans, you know, that we want to be judgmental, we want to put on our emotions into it but we really have to separate it if we're really trying to come up with an answer to a question, because we really have to say, 'Okay, fine. What this person's doing, what this person's saying, it might just make sense for the philosophy that I'm looking at, you know, for this general trend that I'm trying to discover' ... Of course, we as humans are not without emotion, so it's, it's very hard for us to be objective. In fact, I would even say that it goes contrary to our very native, our, our very native selves to be objective.

> **Harold:** Well, objectivity is very important. It's also one of the hardest things for a human being to do, I mean, scientists don't stop being human when they go into the lab ... First of all, it's, it's not free from those things because the scientists are humans, and they don't give up their humanity when they go into the lab. They have a lot of their own personal prejudices and beliefs and so on.

The entomologist Christopher's definition of objectivity appeared to be positivist at first, as he believed in a researcher's ability to step outside one's "biases and preconceived notions" in order to arrive at an answer.

> **Christopher:** Okay. My, I guess I have a simple definition of it, of objectivity: is the ability to step outside your own biases and preconceived notions of the way things work and accept the answers or the data that you get ... Okay? And the reason that's important is because you don't want to interject your own presuppositions into the process. Otherwise you end up getting an answer that is not really the truth or doesn't approach the truth. It's more a result of what your preconceived notions were.

Christopher's later statement on how participants were affected by their work, however, shows his post-positivist worldview.

> **Christopher:** Well, I think they're fooling themselves. Okay, they can say that, but I don't buy it. How could you not? That's just, okay, I'm, that's like saying I'm able to elevate myself above my human being, the nature, my nature as a human being. I mean, I don't buy it. Probably other things, I think they're probably subtle effects, you know, I mean, and the for the most, any person who goes into their lab that day and works with their students, they're going to be a certain, their behavior is always going to be fairly well defined. There are good days and there are bad days and who knows what you ate for breakfast has to do with that, I don't know, or if you missed your coffee that morning, I don't know.

Harold and Queenie, a mathematician, recognized that different researchers could likewise provide different perspectives on the same matter. Queenie related her own experiences in working with her mentor, who looked her research through "a different window." Harold discussed how the truth could only be reconstructed when various approaches were used.

> **Harold:** So it's the same way again that I approach science as I approach life, is that I view that truth is a, is a multidimensional object that you cannot figure out where its boundaries and shape really is unless you look at it from different prospective angles, and you take multiple angles and then you reconstruct the image and relating that to life, the same, bringing it to normal daily life, I always accept *a priori* that people are usually trying to tell me the truth from their prospective, and quite sometimes it's very far off from what I think it is but what I will get is multiple viewpoints and then try to reconstruct whatever the, the real truth situation is, because people can have remarkably different points of view looking at the same set of facts.

David also agreed that anyone could be correct in science depending on their view of the issue at hand.

> **David:** Objectivity is almost synonymous with, with stoic, stoicism. You have, if you really care about coming up with the answer to the question, then you have to walk in with the idea that every angle

> other people have as well as the angle that you might have might possibly be the right angle.

Harold also believed that objectivity, while it was “the truth unadorned” was still bound to be distorted:

> **Harold:** Objectivity is, is the truth unadorned. It’s the, it’s the facts as they are, not as anyone wishes them to be. They’re the, sometimes a lot of distortion comes because of lack of completeness of the facts.

Harold's statement on the lack of completeness of facts was echoed by the other post-positivist participants. They believed that any claim that scientists made was truthful but could only suggest the truth. The epistemological belief of evidence-based, approximate data is consistent with the post-positivist worldview.

Robert, both an engineer and scientist, believed that there were no “one-hundred percent” guarantees in science. David and Larry, a physicist believed that any outcome of good scientific work could reflect reality, and that science was falsifiable.

> **David:** You know, so it goes back to this basic idea that you can’t prove something, you can only disprove something.

> **Larry:** Well, scientific thought, theory should be testable. I think that’s what distinguishes scientific thought from non-scientific thought ... Right? It, it’s not science if you can’t test it. You have to be able to disprove.

Because there was no complete guarantee that a claim was true to reality, the participants believed that all claims needed evidence to support them. David believed that claims had to be supported by theory, and a theory needed to be supported by claims.

> **David:** But to me, you’re coming up with more examples to help explain a phenomenon that you’re saying. There’s, there has to be a check and balance between the data that you’re coming up with, that is, the list of examples that you have, and the theory you’re trying to

> write down, that is something to kind of explain the phenomenon that you're seeing. But it's not just enough to say that there's a phenomenon if you don't have examples to back it up. In the same sense, it's not just enough to have examples to exhibit the phenomenon if you don't have the theory that somewhat explains it

Robert and Queenie believed that claims needed to be supported, whether by experimental tools or logical arguments. Kevin, an entomologist, thought that any claim not backed by scientific principles was not science.

> **Kevin:** If you don't have any science to back up whatever claims you have on anything you have, then that's not science. You know, just having good old boy at the, at the coffee shop saying how great this new drug is that I've taken, that you gave me, that's not science. It needs to be backed by scientific principle, uh – replication.
>
> **Robert:** And if they are presenting some type of argument, if they have some type of, if they're presenting their argument logically, and they have some evidence to back it up with facts and things like that, that's also science as well.
>
> **Queenie:** Now everyone can claim something about this, so science should be methodological. You have to say, for example, somebody claims something and then they, they prove it but when you are proving it you have to use the tools that, that's available to you so you cannot make up anything.

Queenie's statement on science being based on reality or evidence was also echoed by other participants. In their view, science was not only based on evidence or reality, but was also antithetical to magic. Robert and Kevin presented similar views on the subject, although Robert believed that science could one day explain the supernatural.

> **Robert:** That's not to say that these other things that people come up with cannot be proven with science. Like, for example, yesterday I was watching a show about psychic detectives, right? And right now scientists can't figure out how people are able to, and to have these visions and, and, and figure out these things where they have never been before, figure out why or what has happened. It's very strange, but that is just due to our current state of science and technology today ... Maybe later on we'll discover the things, and then we'll figure

> out, oh that's the reason why they were able to do that. You know, it's something that we just didn't understand today. What, like, for example, like if, I guess if you go back in time to make sense of all this, if you go back in time, the first person that saw a car that wasn't being propelled with a horse probably thought that was magic.

> **Kevin:** People tend to think, well, we could do things and this magic, you know, science is not magic. Science is – is real world, and when you start making science a magical thing and, and just saying people can be cured or whatever, unnatural things, it's, that's not science. So, science is, is, is based on sound principles and scientific endeavor and there are a lot of pseudo science things out there, don't, come, that are not science.

Any claim, the participants believed, needed to be validated under three major caveats: (a) repeated testing using (b) different approaches carried out by (c) various independent researchers. For instance, Kevin and Nathaniel would only believe data that was repeatable. Queenie believed that no matter where the experiment was done, the results needed to be the same.

> **Queenie:** Not subjective. It, it shouldn't depend on my decision. It should be objective. It should be the same thing here and in Japan or in some other way ... Yes. Objectivity is important. It should be independent from people's beliefs or politics or some other things. It shouldn't interfere, those kind of things shouldn't interfere with your results.

George, an engineer, found it difficult to disagree with data that had been repeated.

> **George:** They have quantitative data, which has measurable units that, and it produces data that is always reproducible, always, always, but almost always reproducible. Then that produces outcomes that can be measured in the same fundamental units. So that, you can't disagree with data of that type. It's just the way it is. It's like you can't, if a, if a, if a mathematical theorem is proved for all instances, you can't disagree with it. It's the way it is, okay?

Tim, a biologist, stated that he needed confirming results from "two people from two different labs":

> **Tim:** Under given conditions, data should be repeated. So, that is my feeling, objectivity should be there, but data should be repeated, not by you but by everybody else who wants to do it actually.

David and Irene, a molecular biologist, both agreed that various laboratories and various approaches were needed to check the integrity of data. They also both agreed that three approaches could add to the credibility of their findings.

> **David:** One thing I always tell my students is whenever you're doing research you need to check it in at least 3 different ways. So, say, if you come up with a solution for a problem, maybe by hand, you know, of course the first thing is to double check your answer to make sure that you got the right answer ... And then ... to either look and see if someone else has done this before, if it's in the literature somewhere or even talk with other people to kind of see, is this answer something that other people have seen before? ... And then you should try to actually work with other people, talk to other people to see if that actually makes sense or to see what other people have been thinking about this.

> **Irene:** I think it's, you know, multiple observations that agree with each other ... Hopefully performed in different ways, so you do one type of an experiment multiple times and get a certain answer and then you change it up and say, 'Well, if this really behaves this way, then if I did it this other way, I should get the same answer because this is the, this is the trend that I see over here so if I design it in a slightly different way,' and I usually try to think when I design a project for students I, I kind of say, say to them, 'You should really demonstrate a particular phenomenon 3 different ways, whether that be through a biochemical essay, then you probably should test it like in cells, then maybe you should do, you know, with say a microscopic study, stain some antibodies or something. Get 3 different pieces of data that point you in the same direction. It's very dangerous to have 1 technique that you use over and over again to demonstrate a particular phenomenon, because there could be something flawed with that technique that's giving you this type of answer. So you have to, you have to try to demonstrate things in multiple ways ... you, you need to look at it in 3 different directions and get the same answer. For us, it's 3 different types of experiments giving us the same observation.

Irene's views also exemplify the post-positivist view that the integrity of data can also be limited by the technology being used. Bethany believed that publishing results would help other laboratories confirm or disconfirm her work, even if she had no intention to falsify data. Tim agreed that publishing results would help in comparing them with the findings of other laboratories.

> **Bethany**: Uh -What I discover today maybe I publish it, but if it is, if I have falsified it, another lab will try to repeat it and if it does not repeat, you know, they will say, oh the [Participant's Name] result is not correct and now it is possible that I have overlooked something and not that it was my intention to falsify it, that's a different story, but again, as scientists we have to be very astute and very careful of how we collect the data, how we analyze the results, how many times we do the results. Many times I will ask different people to do the same experiment because I want to see whether the results match.

> **Tim:** And then you look at what data you are comparing actually. And that will prove to you, actually – for the researcher, that data is really meaningful, it's actually different – and second, you go to your peers, that data is meaningful actually - and they are convinced that you have done things the right way. And that thing the second important role the professor plays is that to check what you have been working. To make sure that what is published in these cases are really scientifically meaningful.

The participants agreed that systematic methods were required to validate a claim. Such systematic methods, they believed, allowed results to be compared and validated better.

> **Kevin:** Yes. We use standard operating procedures to, this is especially important, well, obviously there's certain new techniques that develop, but once a standard ... way of collecting data should be maintained as a standard operating procedure because this could be, this makes it more repeatable by other people and to have standard methods within each subdiscipline can help people in other locations compare data better.

> **Robert:** Now, having a systematic method to demonstrate that really helps because it allows other scientists to quickly understand what happened ... Because they know the method and they're, you know, seeing someone else, you know, there was, there was also their experiment, having some common systematic method just really helps compare different things as well, so, a scientific method is robust enough to handle many, many kinds of things, but it's not the

> only kind of method, it's not the only way that scientists have, have done that, but it's just, like, a nice common denominator that you can use for comparison.

Robert's brief explanation of the scientific method was repeated through many of the interviews: while there was a standard scientific method, its interpretation varied depending on what scientists wanted to do. Arthur, a geneticist, believed that the scientific method had stayed the same, but the problems had changed.

> **Arthur:** The thing that still um stays the same though is just sort of the general scientific method of determining the problem, defining the problem, coming up with the hypothesis, determining how to test the hypothesis, and actually conducting the experiment, those are still really the same. It's just the problems that we have that we deal with are now just much more complex.

In general, however, the participants believed that a scientific method needed hypotheses, controls, statistics, and appropriate sample size. Fred, a geneticist, Tim, and Kevin believed that statistics was the best way to evaluate data. George believed that numerical data was robust, but that there were still many other kinds of data that science could use. Bethany summarized these views in her statement:

> **Bethany:** The way I understand it is that first we start with a hypothesis. Um - So, the hypothesis um can be right or wrong. Uh - Then if it is right then we accept the hypothesis. If it is not right, we reject the hypothesis. So our work is hypothesis driven. This is number 1 about the scientific method ... Uh - Then it is important to have controls, positive and negative controls. That's where the objectivity comes in. Uh - Then we carry the experiments a number of times, at least 3 or 4 independent times. So that we can see what, whether the results um fall into a particular trend or not and then uh we do perform statistical analysis to see if somebody else was going to do this experiment, what would be the probability that they would find the same results, okay? So this is what is the scientific method. It

> is the hypothesis driven and then it has – the results ought to be reproducible.

The scientific method, the participants believed, was not simply following a series of steps, but knowing exactly what one was doing. A critical, logical method, they believed, also promised to yield good results. For instance, Bethany believed that good controls methods ensured that researchers would interpret the data the same way. Arthur, in particular, believed that a scientific method done anywhere would help ensure that research is unbiased.

> **Arthur:** Sure. Yeah, so um I guess what I'm thinking about is that if somebody is following a scientific method it doesn't matter whether they're at um, a government research lab, a university, um where we typically tend to think that unbiased results are coming from or whether they work in the industry and actually have a stake in the results that are - maybe a product under it being developed. Um - As long as the scientific method is, is followed and the data is collected appropriately, then to me it's still unbiased research.

Not all the participants, however, believed in all the steps of the scientific method. For instance, David and Fred did not believe that all work needed to have a hypothesis.

> **David:** ... Well, one of the things that I actually don't like about this naive version of the scientific method, you know, one of these things that maybe you learn in high school or elementary school is that you're already starting with a bias, you know? You're supposed to come up with a hypothesis ... Now, a true scientist doesn't have any hypothesis. They just simply say, 'I'm going to go in here. I know there's something happening here. I want to find out what it is' ... So what I'm saying is, a true scientist in his methodology would then try to look at the data and come up with different questions to ask as opposed to going in at the beginning and saying, 'Here's my hypothesis. I'm going to try to prove it.'

> **Fred:** There's all kinds of other things that don't necessarily come from a hypothesis, so in that respect, not all paper, not all that's published in science and not everything that leads to a scientific breakthrough is necessarily following the standard method in terms

of observations, hypothesis and testing. Some of them, you just, it's a fishing expedition and you just sort of, you simply see what you find and you have no idea and the problem is you don't know at the beginning to, oh, you could. You could make some, some dummy hypothesis to try to have something to test, and sometimes we do that for publication just because it simplifies the writing in my opinion, but, but a lot of, a lot of what we do sometimes does not have a clear hypothesis.

To Harold, the hypothesis was needed, but the scientific method was not unique. In his words, "That doesn't make it ours."

Harold: Too much is made of the scientific method. Basically, a hypothesis is a guess and what I tell my, this is also what I tell my students. I say that it's, it's, we have to, we have to place our bets before the horses cross the finish line. Otherwise it's not fair. So that's what we do in science and we test things, but we have to be willing to throw away things even if we, even if, even if we really want something to be one way, that doesn't make it right. That doesn't make it ours.

To George, however, a fishing expedition still required a hypothesis.

George: I, I, I can be rather dogmatic about that in that everything, even though there's different approaches and this, and there's applying for grants, there's like, discovery science and hypothesis-driven science. I think most discovery science can be converted into hypothesis science so bona fide scientific method is, well, it depends on where you start on the process. We have observation, hypothesis, tests, comparisons, support or refute hypothesis and iterate. I think even discovery science where looking for factors that you don't know is a form of hypothesis science, although in my opinion a rather misguided hypothesis science because you're kind of, they always use the idea of fishing for results or fishing for data, but any good fisherman will tell you that he doesn't just go out in the middle of a big body of water and plunk his line down without studying what it is he's looking for or catching. People who go fishing like that usually quit fishing, because it's boring and they don't catch anything, whereas a good person who goes fishing will study the time of year, the water conditions, the, you know, history, the weather patterns … the type of bait fish in the area and then look for 1, 2, or 3 different types of specific species of fish. So that's proper discovery doing the science even though, I mean, there's, so there's some push about development and discovery science, but I think that everybody can provide a hypothesis statement that they want to test. It's just a

> matter of how hard you want to think about the problem before you go out there and do it and make a bunch of mutants or something.

As Harold mentioned earlier, the scientific method is not unique to science, but scientists still advance knowledge through their use of the method. For instance, while Fred thought that such a method was successful, he realized that it had its and was still trying to solve problems. It was only unique in that it could help scientists analyze their data better. Such a view is consistent with post-positivist thought.

> **Irene:** I don't think it's, I don't think it's any, anything really unique about it. I mean ... I think chefs working in a restaurant have the same type of a thing. They're constantly experimenting with their sauces and their presentation and their, and, and their outcome is who likes the food and, and what is a successful dish, right? So, you know, it's, you know, what, what is the most, you know, attractive to people? What, you know, tastes the best? What is, you know, what is a winner. What is unique?

> **Arthur:** Because everyone is solving problems every day. Uh - That's partly what makes us humans as a species, but I think what is unique about science is that, you know, typically scientists have, um I think, a different curiosity level of being able to um dig into problems and really drill down to find um, to find solutions or to find answers.

> **Patrick:** And a lot of what they do is they go out and they plant grass seeds, and they grow them and they fertilize them and they mow them, and it's the same thing that the guy who mows at the old lady's lawn next door. I mean, he's doing the same thing, day in and day out, except when he's done he throws the clippings in the back of a truck and drives off. These guys, when they're done, they take their clippings, and they weigh them, and they analyze them and they look for diseases or whatever it is that their, their research is about, so what really separates a scientist from a non-scientist is how they go about their job and what the objective of that job is.

> **Harold:** The, so scientific method in that sense is, is a little overplayed, and I think that people get tired of hearing it. It makes it like it's some mysterious process. All it is is good critical thinking, you know, it's no different than good critical thinking in non-scientific fields.

> **Larry:** I mean, to some extent every kid is a scientist ... Well, because kids explore. Right? And unfortunately, somewhere along the line

> some of them lose that inquisitive nature. So we had an outreach coordinator who, who made that very point to kids, especially younger kids, when she would do a demonstration or, or give them some hands-on activities. She'd say, 'See, you're acting like a scientist.' So, it doesn't mean you have to publish in Physical Review Right? That, that's, the bar is not that high. I think really anybody who, who asks questions of nature and, and pursues them is acting like a scientist.

Because claims were never final, and also depended on good methods, technology, and replicability, the participants likewise believed and acknowledged that knowledge changed.

> **Tim:** That is all we can say with science. In science we know that time will tell. Everything is science, actually. Everything that we do is going to be science, actually.

> **Fred:** ... now I'm a much more skeptical, I know, I know how things are done and you get some experimental results and you've treated them the best way you can but that may not be correct, and so what, but you have to write something in your, in your conclusions of your paper, so you say, 'Well, this is what I think it means,' but it may not, it may not be right, so now I think I'm much more skeptical about a lot of things and realize that it's all a, science is a process, not a, not necessarily a result, and the result is constantly changing, so you have to not take it as anything static.

There was still knowledge that was already accepted and established. Oliver, a physicist and positivist, believed that current statements about nature describe and predict it correctly.

> **Oliver:** Well, I think the, the, I would add to that that the stuff that gets into books by definition is that stuff which you've already processed enough and where an agreement has been achieved ... At one point I'd like to emphasize to the general public, which, you know, often they don't hear is that all the stuff about Einstein and that space time and black holes and all that, all that stuff which people think is either cute or incomprehensible, all that stuff would be useless and uninteresting but for the fact that it's correct in the sense it gives a correct description of nature. So, I mean, a lot of these funny things which you either like or don't or find cute or not are in the domain of science because they give correct predictions.

As Tim said, however, science takes time; and as the participants believed, the great discoveries took time and basic research to finalize. Research would eventually benefit humanity, but in the meantime, research was also being built. Queenie believed that all research would one day come together to benefit humanity in various ways. Patrick, an environmental chemist, called it an "investment in the future":

> **Patrick:** Well, what makes it unique is that very often what we're doing is, is, is, sort of providing an investment in the future in that we are hopefully studying something and providing results that if not immediately, maybe in the next generation or two of experiments will start providing useful results that, that will make a difference to people.

The scientists believed that the knowledge that science generated was neither good nor bad, and that science was "a double-edged sword," as some of them put it. However, this also meant that science required regulation in order to control what scientists could do.

> **Fred:** The problem, of course, with most science is you, is, if it's like guns that people say, 'Well, guns don't kill people, people kill people.' Well, it's the same thing with scientific products. They're just tools, you know? So something that could be very beneficial in some cases could be very bad in others and it's how it's used rather than the technology itself that's, that's the problem, and so, certainly some things should be … should be regulated for sure....

> **Harold:** That was one of the things, so realizing that science was a double edge on anything and you quickly have to assume that anything that you develop could be used for more than one purpose, and that had a very sobering effect on me.

> **Robert:** Well, I know - scientific field is, there is pros and cons [*sic*], you know, lots of people will misuse it ... You know, so if, for example, someone will create something, like, let's just say, you can give an example, the Internet. If someone, some scientists created the Internet so they can communicate with each other. Now the good thing about it, it just took off like wildfire, right? It's now being used

> by people who are not scientists who do great things with it ... So that's good. They, they took the science and did these other things. But then you have all these other bad things on, on, on the Internet too, like, people looking for young children, for example ... So, it would be nice if lots of people who use science are, are, even if there are people out there, and their job was to monitor these kind of things. When this new technology comes out, monitor it in such a way to try to predict how people can misuse it and sort of package it so that couldn't be, you know, couldn't be happening.

In line with these beliefs was the post-positivist notion of a science that was embedded within society. The participants believed that science needed to be regulated, needed funding, and could never be divorced from its social and political implications. Therefore, researchers needed to be regulated, but also needed to be ethical and moral in their work as well. When asked about their opinion on science and society, all participants, regardless of their worldview, acknowledged that science could never be isolated from society. For instance, Oliver, a physicist, was a positivist in most of his worldview, but did not discount that science was also part of society. Michael, an engineer, as well as a post-positivist, believed that economics regulated what kinds of products were out on the market. The rest of the participants talked about the various ways that science was integrated with society, but many concentrated on the funding aspect of research.

> **Oliver:** And of course science is critically dependent on government funding, and so a lot of what people do is to do whatever looks like the government is going to want to fund. So I think science is a part of society just everything else, it's just like politics, religion, education, all these things come together.

> **Michael:** No, because economics plays a major role in engineering, I mean, if, if, if the economics didn't play a role, things would be significantly more expensive and significantly last longer, so, so, so is, is the economics a part of this? Yes indeed. What can we do in with, with available products that we have in order to make them last a certain length of time and so on and so forth, yes indeed, economics is

> a huge part of engineering, and it will continue to be a huge part of engineering.
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> **Harold:** But more than that, in particular science as it's practiced today, I mentioned to you it costs a lot of money to do science because a lot of the easy stuff has been done. Science gets harder and it gets more expensive. Because it requires raising large amounts of money, it very quickly starts getting swayed by, first of all by what's hot and what's not.

Because scientists believed in a socially-embedded science, they also believed that science owed a debt to society. This view will be tackled further in the next subsection, which deals with the culture of science.

There were two exceptions to the post-positivist worldview. Ernest, a geneticist, and Oliver, a physicist, tended toward a more positivist worldview. They both believed that scientists could be completely objective and unbiased:

> **Ernest:** Objectivity is where you're completely unbiased and you have no, um - you look at the results, you look at the design of the experiment with absolute unbiasedness, absolutely with no forethought of, of basic pretenses of what's, you know, right or wrong, of what you accept and don't accept.
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> **Oliver:** ... scientists are people like everybody else. I like to say scientists are kids just like all the other kids on the block. We're no different than anybody else. We have likes, dislikes, jealousies, you know, ego, all those things show up in science. It's just that we try to control them in various ways ... Being able to divorce yourself from your biases, which we all have, to look at data and theory in a way that allows you to conclude that your, yourself that you're wrong. So, we all start, at least I start from the assumption that I'm biased. Everybody I know is, I'm doing this thing because, I'm doing this experiment because I think the results will be interesting. I want a certain set of results to happen because I'm biased to make that happen, but then I say to myself, okay, you're biased to make them happen. Let's do all the things you can do to make sure that you do not impose that bias on the data by selectively analyzing the data or analyzing it in a way that makes results come out which are actually not correct ... Because if it's, it's very easy in doing experiments and analyzing data to bias the data by virtue of your non-objectivity to come up with spurious results.

Despite the fact that Oliver acknowledges that scientists can be affected by their personal biases, he still believes that objectivity comes from being able to set all the biases aside and see the data for what it is. Such a view is consistent with positivism. Both participants also believed that the scientific method was unique to science. Nevertheless, Oliver and Ernest also shared some of the beliefs of the rest of the participants. For one, Ernest acknowledged that knowledge was changing, and that researchers needed to keep an open mind when they encountered "weird science".

To summarize this section of the results, the majority of participants espoused post-positivist beliefs, with the exception of two participants, who were positivist. The post-positivist participants believed that objectivity was possible through validation of research results by repeated experimentation, using good methods, by independent researchers. They believed that they could only approximate an objective reality. They also believed that science was a part of society, was affected by it, could not be divorced from it, and should help society.

What is the culture of the researchers?

When the participants were asked to describe their culture, they generally fell into two groups: those who believed that there was a global scientific culture that superseded all national borders, and those who believed that science and engineering were too broad to be generalized. For instance, Steven, an engineer, did not believe that it was as easy to define engineering in the same way that he found it easy to define scientists.

> **Steven:** ... I just, in some ways I almost feel like those are ill-posed questions because you just can't, there's not a good way to answer that, you know, it's, it's, it's, because it's such a vast, a vast, especially engineer. Scientist you can probably define more easier [*sic*] than engineer, more easily.

Tim, however, differentiated between the cultures of scientists and engineers:

> **Tim:** ... They take preexisting knowledge or creating knowledge, what's a need, and they transform it into a product. And that's why they call them – the engineers are scientists. There's a very different – a big difference of scientists and engineers. Engineers are product-oriented. They're creating products. Scientists basically don't think about whether it's product oriented or not – they study basically what's going on. But both of them make equal contribution because they take the scientific principles and try to convert it into a product.

To some of the participants, the scientific culture was global. To Robert, it was due to the fact that students needed to work together inside the laboratory, whether or not their countries were warring outside of it. To the other scientists, it was the shared language of science that bound them as a single culture regardless of where they came from.

> **Harold:** I'll make a provocative statement. I said that scientists are more like each other frequently, than they are like their own country people. So we go to international scientific meetings, I made that, actually, I, I, I brought that up at one years ago at a meeting and everybody kind of thought about it for a minute and then said, 'You know, you're right. We really are more like each other than we are like people in our own country.' And scientists are frequently, and, you know, very, very small minority.
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> **Robert:** But that's what they're comfortable doing, right? But still, even though you may have people warring in other countries, I do know that if they come over here to be grad students they actually work together, right? (laughter)
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> **Nathaniel:** Well, I've had to spend a lot of time in Brazil which is a 3rd world country, and I've also spent some time in Italy, which is supposed to be 1st world but is somewhere in between (laughter) and I was, scientifically, again, you know, things were similar. I

mean, I don't see a big gap between the way I think and the way they think, because we're all trained in basically the same ideas and tools and how we use those tools is the same.

Patrick: ... Well, science is more global than that. Science itself is the, is the global community and you can say, well okay, but you've got non-science, okay, fine. So within the scientific community, yeah, you do have people who kind of think, basically, along certain ways.

Fred: Yeah, certainly we do have something, (laughter) I would say. Um - But we, it's very, of course a very diverse group that does science, especially nowadays, and we've had lots of people from all over the place and we interact with all of our colleagues. But certainly we, we are tied together, well, it depends on who, which ones you talk to, but certainly tied together by a common way of looking at things in terms of wanting to get at the truth and wanting to test things ... and the whole culture of stress, of needing to publish, of needing to be out there all the time and constantly fighting for funds and all that kind of stuff, that kind of leads to a commonality there, I think, that is the same for everyone all over the world.

Oliver: The, the, scientists tend to be less, I would say, nationalistic in the sense that we're all scientists first, we're cooperating on various projects. I've collaborated with people, all sorts of, you know, nationalities and whatever. It's, it's irrelevant. All we care about is that you know something that I want and let's get together, and I have something you want and let's make a paper out of this, okay? ... The other part of the culture is, you know, a recognition, a common agreement of what the scientific method is, a generally shared sense of enthusiasm for new ideas and a willingness to accept them at some level, and I guess common traditions, the fact that many contributions to science are made from scientists from all over the world, so we know that it isn't all American science or Russian science or German science or British science. It's science and what helps that along is that many people, as you heard me, have studied in different countries. I mean, you look around here and we have students from all over the world, like you, and, and nobody cares, you know, where you come from. People have postdocs and travel to Europe for conferences and, you know, I've been to conferences all over the world, and so it's, it's this homogenizing of, of cultures in a sense, and you really don't care about, you know, about those issues. I mean, I can just, feel just as comfortable in Copenhagen as I do here because you have a common set of views and so on.

Michael: Well, it's very similar. I mean, we, we almost have a language that we talk to one another, so, and what brings us together is really the science of engineering. I mean, that, that's what brings us

> together and we're able to communicate with one another with sound engineering foundations and so, very similar.

Oliver's statement on unity through the scientific method can be traced to his positivist philosophies. Harold saw the common bond as something beyond the scientific method, went on to talk about the science culture. Harold believed that in its global reach, the science culture united scientists in terms of how they viewed the world.

> **Harold**: … It's, for all of the reasons we've discussed earlier about the principles, the basic principles and I'd say that's more important than any 'scientific method' as if you could follow this, this rigid little algorithm about how to do good science. But it's the principles holding those to heart to be able to, it, it, it's a worldview. It's a way, a certain fundamental way of viewing the world, the people in it and what should be done and shouldn't be done and how we should conduct ourselves, and I think it's really a set of values. It really is a society. We call it scientific societies, and I think that that's not totally by accident. I think we're trying to say something when we say that, that, that it is something, that we hold certain values in common.

George, on the other hand, did not believe that there was a single scientific culture.

> **George:** I can't really answer that question because I've seen the scientific culture in the United States, and it's very different than how the culture, the scientific culture is in Japan ... and India and other places. Even, you know, I think the scientific culture depends on the culture that it's in. There's not one global scientific culture … that kind of captures all those differences between the scientists who are part of different cultures.

Some of the participants believed that there were subcultures within science. For instance, Nathaniel believed that one's home laboratory or institution dictated how one worked and what one believed in science.

> **Nathaniel:** ... They just, I don't know, the, the scientists in the laboratories, the federal laboratories, were paid to create systems to basically, in this case, defend the United States against its adversaries. And that makes you think one way, and somebody, for example, coming out of Harvard, he will play a more altruistic attitude, and it will be very dissimilar to what someone in one of those laboratories might think ... I wouldn't say scientists are all one happy family. They're not. Not at all, actually.

The differentiation among subcultures was extended to how researchers from the academe were different from researchers in industry. To the participants, being in industry allowed one to earn more, but at the expense of having the freedom to choose one's research project. Being in the academe, on the other hand, allowed researchers flexibility in choosing what research projects they wanted to carry out.

> **Robert:** ... And I, and I, and I just realized that, well, if I go into industry I'll be working on, you know, maybe one of my ideas, and that one idea had to be something that relates to the company I work for (laughter) so that really narrows it down. But if, if I'm a professor then I can work on many things, various things and almost anything I want to work on.

> **Queenie:** Oh, I, I guess so because when you, when you get your degree like Ph.D. degree, then most of my friends, they, they want to go to the industry because they are, they are paid a lot, but I, I think that we are getting less money but we are more flexible and we, I, I think that is more important. The being free or doing what you want to do is more important than getting a lot of money, so, if you, if you, if you go to industry then you are working with someone else, and they want you to do something like for a long hours and even if you don't want to work with them or you don't want to work on that project, you have to do it because they tell you to do it, but here it is not like that. So I get what, I get what I want to do and that's the most important thing to me is being free and more flexible.

> **Patrick:** Well, industry scientists and, I more or less was one in the first 2 years. You will have a very focused set of objectives. When you come into academics you're given a topic area, you know, environmental chemistry or something to study. Environmental chemistry covers thousands and thousands of topics. You work for an

> industry and they're not going to give you an open-ended assignment like that. You will be working on something very specific, and I've worked with dozens of industrial scientists in, in my work and even those in the industrial environmental chemistry have very specific tasks that they're supposed to be doing. So yeah, it's, it's a totally different route. It's a, it's a business model versus the academic model, a lot more freedom for us than for them. There's an obligation to their company as well. Sometimes there's the perception although it's not necessarily true that there, the results could be somewhat compromised.

To some of the participants, the nationally-influenced research cultures were more differentiated at the undergraduate level.

> **Larry:** Well, I think generally speaking, a Korean student is, is not, is going to be a little more formal with his or her advisor, maybe not question his or her advisor ... You know, more, more, you know, professor up here, grad student down here. U.S. students do not, (laughter) it's not that there's any disrespect but, but there's a difference in cultural attitudes.

> **Steven:** Well, I mean, I think that the, the undergraduates characterize them as they're bookworms or they work really, you know, they like to study and, you know, maybe they're into math and science and things like that. But I don't, I mean, definitely I've heard these sorts of things said by students before, so, whether, you know, that is a reality and backed up, I mean, maybe there's some sort of admissions process filtering through anyone who, you know, has that, but, I don't know.

To Larry, the cross-national differences were apparent even at the graduate level:

> **Larry:** And even at the graduate level, well, okay, so let's, I'll give you an example. In my Science and Society class, I, I want, want the students to write ... So, so I'm not doing hard science in the sense that I'm not giving them exams based on equations but I want to hear, I want to understand how they're thinking. And some of the international students aren't at a considerable advantage because their writing skills are not as polished … as a native speaker, so that, you know, that's something I have to take into account.

In this section of the results, the participants' views about the culture of science will be presented in detail. These views were obtained by asking participants what the jobs and responsibilities of scientists were, which yielded responses on the norms of science. Questions on the standards of success yielded responses on what the scientists valued in their practice. In asking the scientists what scientists should not do or be to be successful, the researcher also received responses on the sanctions and punishments of the science culture. In inquiring about the scientists' experiences with science in school, the researcher uncovered how scientists were socialized into the culture of science. All these aspects of the perceived science culture will be presented in generalizations in this section.

1. The epistemologies of science undergird its values and norms

When scientists were asked about their values and norms, albeit indirectly, they also made references to their worldviews as scientists. In particular, they discussed how they viewed knowledge, and what these views of knowledge meant for scientists. These views on knowledge, or epistemologies, were already presented earlier in the section on worldviews. These include the following views: data must be repeatable using systematic methods in order to be validated, any claim must be based on evidence from good methods, knowledge changes and many discoveries are built on years of basic research, knowledge is neutral but must be regulated to avoid negative impacts, and science is embedded within society.

- The values of science include advancing knowledge and the scientific field, objectivity, ethics, having an impact on society, rigor and good experimental design, integrity and honesty, and passion for learning

When asked about their views on success and what responsibilities scientists held, the participants' responses generally fell into seven major categories of values.

The first was the need to advance knowledge and the scientific field, which was borne out of the need to advance knowledge, a value which was discussed at length by participants such as George, Harold, and Irene.

The second value was objectivity, which the participants already defined earlier as part of their worldview.

The third value was ethics, which was correlated with serving humanity, and which is therefore linked to the epistemological belief that science and society are interlinked. Participants such as Jessica, veterinary scientist, discussed how ethics was essential to their research work. Tim linked ethics and objectivity.

> **Harold:** Ethics is absolutely essential. Religion is not essential. You can have a very ethical well-meaning, good acting person who has no religion.

> **Kevin:** To be ethical ... In your scientific endeavors ... You have a responsibility to be an ethical person and ethical procedures, maintain uh standard operating procedures and proper experimental design and, and if, and, and in most cases proper statistical analyses ... And not cheat the system and not cheat the science.

Research work needed to also have an impact on society, a value which is closely linked to the norms in the next section. This value is likewise borne out of the epistemological belief that science and society are interlinked.

The fifth value was rigor and good experimental design, which is borne out of the epistemological belief that repeatable data is obtained from good methods, and that claims must be backed by systematic methods. This value was linked to norms, and will be explored in the next subsection.

The sixth value was integrity and honesty. This value is closely linked to nearly all the epistemological beliefs that the participants held. They needed honesty when analyzing data and making claims, as well as in reporting results to society and avoiding negative impacts of their work.

> **Patrick:** I mean, underneath all of this has got to be this level of honesty. Honest with yourself, honest with people you work with, honest with, if you're a scientist and generating data and you've got to be honest about that. So, it's, it just goes on and on. It's really tempting to take the easy way out all the time.

> **Ernest:** Yes, and it's a matter of how much time do we have to do it, but I'm old school. I think scientists should be very high integrity, they should be very honest, and they should, you know, lay things out factually.

The seventh value was passion for learning, which participants often discussed as a love for learning or a love for work. Such a value may be linked to the epistemological belief that knowledge changes, so that researchers must always be willing to learn and keep their minds open.

> **Harold:** I think that a scientist has to love his or her work because if you don't, and I don't say love it in the sense of possessive. I mean enjoy it ... Because, as I, I also tell my students, you know, if you murder somebody you only get 20 years, but if you're going out for a career after your Ph.D., you've got 40 years to life, so, you might, you better enjoy what you do. It, it should be, and that passion has to be there. So I want somebody that has, is not only objective and hard-working and good at what they do, but they have to have at least a little passion for it.

> **Patrick:** The answer is pretty, pretty simple and that is that, you know, maybe 25 years ago my answer would have been different, you know, you've got to work hard and you've got to find an area that's really hot and you've got to get into that and stuff. Now, the bottom line is you've got to do what you want to do. You've got to find something that you really enjoy doing that you love doing and, I mean, if you really hate working and you hate going to school and, and you don't want to do anything except nothing.

To summarize this section of the results, participants valued advancing knowledge and the scientific field, objectivity, ethics, having an impact on society, rigor and good experimental design, integrity and honesty, and passion for learning. These values were found to be based on their epistemological beliefs.

- The epistemological beliefs and values of science give rise to its norms of: open-mindedness, critical thinking, admitting one's mistakes, careful and systematic work, asking questions and exploring, learning and establishing a firm knowledge base, truthful communication, working on high-impact research, disagreements amongst scientists, and mentoring.

The epistemological beliefs and values of science together gave rise to the norms that the participants discussed when asked about the jobs and responsibilities of scientists. In general, the norms that the participants discussed fell into ten general categories, all of which were discussed in light of the participants' epistemological beliefs and values.

The first norm was open-mindedness, which was defined as analyzing data without placing any preconceived notions upon it, and welcoming all findings whether or not they agreed with one's hypotheses. The norm of open-mindedness needed to be practiced because scientists were required to be objective, and because knowledge was constantly changing.

This norm was described in detail by Ernest, who had been exposed to what he believed was “weird science”:

> **Ernest:** And, and, and when you get into some weird things, you’ve got to keep an open mind that maybe what you had been taught in the past isn’t quite right because you’re discovering something new ... that defies what you learned when you were young ... sometimes you find something like a prion and it just totally befuddles you, and there’s still scrapies in sheep, and it still is defying biology. So, every once in a while you get into weird science, that’s real science and you’ve got to open up your mind to a whole new can of worms.

David and Jessica agreed with this view, and returned it to the fact that the scientific method did not always require a hypothesis in order to be carried out.

> **David:** On the other hand, say that you are trying to look for examples for this certain phenomenon that you're looking for. So then of course you're going to focus the data as much as you can to come up with as many examples as you can. But then, that's why I'm saying, it totally depends on what you're looking for. You know, are you really just trying to walk in with an open mind to say, 'I'm just going to look for as many different interesting ideas as I can with this data', or do you want to say, 'Okay, I have a theory. I want to know if this theory makes any sense, so let me come up with as many examples as I can.'
>
> **Jessica:** So objectivity is everything. You can't just because it doesn't, the data doesn't say what you want it to say, it doesn't, as a matter of fact, some of the most important findings have been based on the fact that they don't support a hypothesis. That doesn't mean that it's, that it's wrong. You just have to follow what the data says. And then don't be too unwilling to change because you could be wrong too.

Jessica's response can also be traced to the ontological belief of scientists being limited by their own views, and the belief that researchers see different parts of a problem differently. Larry's response echoes hers, and correlates open-mindedness to also being open to critiques and alternative points of view.

Larry's response on the jobs of scientists included both being open-minded to all kinds of data, as well as the norm of critical thinking. The norm of critical thinking, according to many of the participants, meant being skeptical about their data. This norm was associated with the epistemological belief that knowledge changes, so that researchers had to look at their data critically to ascertain whether what they were seeing was an artifact or new data that changed previous thoughts on an issue. Critical thinking was also associated with objectivity, as well as integrity and honesty. For instance, Larry related his experiences in physics research, where he had to work with a student and be critical about the findings that they had obtained, which, it turned out, were only artifacts of their research methods. Harold defined critical thinking in light of the scientific method, and knowing exactly what one is doing so as to ascertain whether a result is wrong or correct.

> **Harold:** So the scientific method is to, first of all, to be absolutely, brutally honest particularly with your own work and second of all, to do things in a way that you always have as good an understanding as possible why things happened as they did because even a positive result can be wrong.

To George, critical thinking was correlated with creativity.

> **George:** (pause) Don't, don't put yourself in a, in a bubble ... where you focus so tightly on one small aspect of a project that you lose focus of the greater context of where it fits in. Uh – that's probably two that I think of right away. I guess don't be afraid to question scientific dogma ... You know, don't be afraid to be creative.

Oliver's response agreed with George's. In addition, Oliver discussed the concept of the Lore Law, as he discussed how research was essentially questioning dogma.

> **Oliver:** You see that it's, what's taught to you is often not accurate, very often not accurate. That's been a theme of all my research, is questioning things. I guess that's the theme that's going to emerge. And questioning, questioning often leads to conclusion that what you're told superficially is not really the way things work. It sort of works. I have given a lecture on something called the lore law, l-o-r-e … the lore law is that the lore is always wrong. The lore is what we talk about in science, sort of the generally accepted view of things, and my definition of the lore is, it's those that umbra, that surrounding set of concepts which are implied by things which are correct, but which are themselves not right, so often in science one generalizes some result to, to a point where it's not accurate anymore, and that's what we call the lore. It's the things that everybody sort of believes are true but which when you really think about it and look at it much more carefully turn out not to be true.

The third norm is closely related to critical thinking and open-mindedness. Admitting one's mistakes, the participants believed, was the job and responsibility of scientists. Such a norm can be traced to the values of objectivity, integrity, and honesty, which, in turn, can also be attributed to the epistemological beliefs of knowledge changing and evidence-based claims. That is, with no evidence to support their claims, and with knowledge changing, researchers must be willing to be honest and say that they are wrong.

Some of the participants related their personal stories on how they needed to be honest about their data analysis when their findings were debunked by other scientists. For instance, Fred had once tried to explain how certain genes had been mutated in an organism he had been working on, and he had refused to change his views, until he realized that his model was wrong and that other people's models were correct.

> **Fred:** And it was just that I had this idea that it came from another thing, and I didn't want to look at the other data until it became so numerous that it was like, oh man, I can't, this, my, my, my pet idea was not tenable really, the simplest explanation, was, was, was probably the correct one ... Now, I'm fine with it, but for a while there, it was, it was tough. It's tough to give up your preconceived notions sometimes, and so I think objectivity is very, very important and you have to, you have to be willing to set aside what you believe even if it's a long held belief and come around and say, 'Oh well, the data actually doesn't support that. It must be something else.'

Fred's views were echoed, and in general, by a majority of the participants, including Patrick and Ernest:

> **Patrick:** I mean, whether or not it's listed in the formal definition of what the scientific method is, it's got to be a great deal of objectivity in there and willingness to change your mind if the observations you make don't support your original concepts or hypothesis.

> **Ernest:** So, and if you're wrong, admit you're wrong sometimes or admit that that's what your data showed you, and once in awhile you will find out that what you were measuring wasn't what you thought

> you were measuring ... And there's still a slight chance that you misinterpreted the data.

The participants also expected that all researchers were expected to carry out careful and systematic work, a norm that they related to good experimental design, ethics, and rigor, which were seen as values. These values were traced as well to the epistemological beliefs that data must be repeated using systematic methods, any claim must be made on the basis of good methods, and the negative impacts of knowledge must be avoided. Careful work was also defined as hard work by scientists such as Irene, Tim, Fred, Ernest, and Harold.

Fred believed that all scientists were responsible for regulating their own work.

> **Fred:** I think, a responsibility of all scientists to evaluate their own work and think about, hey, wait a minute, is this a good idea? You know, some things, of course you can't predict, but, but for the ones that you can predict, you need to take appropriate actions

Patrick and Steven believed that all researchers needed to be careful about their research work, and that they had the responsibility to ensure safety if they were working on safety-related issues or research. In addition to doing good and careful research, Tim and George believed that science had the responsibility to do no harm.

Researchers were not only expected to do good work, but to keep on asking questions and exploring. This norm was often mentioned along with the value that research must advance the field of science. This norm was also correlated with the fact that knowledge changes, a good deal of basic research builds into discoveries, and data must be repeatable. For instance, Robert believed that science would one day be able to explain the supernatural, but to do so, it needed to keep asking questions and doing careful research. Many of the scientists mentioned the norm as a responsibility:

> **Christopher:** Responsibilities of scientists, I think, are to ask interesting, interesting questions, inquire into uh uh useful areas, things that … ask questions that might be useful to society but not purely. mean, I think there's a need for scientists to be willing to ask questions just for the sake of knowing, right? It doesn't necessarily have to have any societal benefit or ramifications immediately. Yeah, it's our job and our duty to keep pushing the frontiers of knowledge. That's it.
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> **Bethany:** So the Iron Lung, that was not the answer. Although it brought a cure, a solution to the problem, the answer and the real cure was the development of the polio vaccine, which took a lot of basic research to get through. So, but, you know, we are part of this system now and we cannot give millions of dollars to science when other people are in trouble.
>
> **Tim:** Scientists have a feel for making new knowledge – knowledge discov - We call it discovery. We don't call it 'creating.' We discover new knowledge as scientists. And I think that is what makes scientists very special, actually. Because, without discovery of knowledge, no other profession can progress, actually ... In my opinion, basically scientists are those who make sure their work makes a contribution, actually, a tangible gain. They make a lot of knowledge, move knowledge further – but you know actually, scientists knowledge, they might not have an immediate application. Scientists should be able to bring knowledge which can be used tentatively for making more knowledge.
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> **David:** I know this is not a popular answer, but I strongly believe that the responsibility of the scientist is to ask questions and try his or her best to come up with answers to those questions.
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> **Oliver:** Well, it depends on what area you're in. A successful scientist makes a major contribution to the field that he or she is in, so if you're a physicist and you're, you're, you've come up with the theory of relativity or quantum theory, a theory which massively changes our view of the world, okay, that's a successful scientist. If you're an experimentalist, a person who does a very clever experiment that shows something new that we haven't seen before, in each of these fields you can do relatively mundane things which push, you know, kick the can down the road a few inches or you can do, you know,

> incredible things which totally change our view of the world, like Einstein did and Niels Bohr, and all those guys. So a successful scientist is one who has made a major impact on, on his or her chosen field. If it's biology, it's Crick and Watson who figured out the structure of DNA. It's always, you can look at the landmark people who have done the landmark things, but, I think that's a good yardstick, yeah.

George believed that true science meant working to push knowledge forward regardless of the availability of funding.

> **George:** ... I think scientists love to work and love to find new things. Perhaps there's a time of, a period of time where they can't pursue precisely what they want to pursue because of that type of situation, but they can pursue things that are analogous to their, their perfect, you know, the idea of a prefect project would be that still pushes knowledge forward but pushes knowledge forward in a field that is supported by the people who hold the paycheck.

Another norm that participants believed in was establishing a firm knowledge base. When asked if they believed that a doctoral degree was essential, 16 participants did not think that it was, but they all agreed that some amount of training and learning were necessary in order to carry out good scientific work. Scientists needed to learn and update their tools, a norm which is also consistent with the value of passion for learning, and which is likewise traceable to the epistemological belief that knowledge changes, and scientists must therefore be open to learning at all times.

> **Bethany:** ... First of all we investigate something. We have a certain amount of education. One cannot be a scientist without uh knowing certain things about the scientific world ... so there is a lot of years of hard work that goes into the making of a scientist. And, so on the one hand it is the education, uh the knowledge that, the knowledge base that one has developed. On the other hand it is the thinking and that does not come overnight.

> **Queenie**: ... Responsibilities, well, the, you have to do research, and you have to improve yourself, constantly improve yourself because if

> you, if, if you are doing the same thing, like 10 years, there is no point in doing those things, so you have to improve yourself. So you have to be open to other new problems and it is, it is okay if you, if you are working, like a grad student, if you don't know anything and you have to work on it, so that's the first one.
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> **Kevin:** Well, in our field we emphasize at the undergraduate level to get the basic sciences concepts, you know, chemistry, physics, math, to grasp basic science at, at the undergraduate level and then as they focus into what directions they ever want to take, even if they end at the bachelors level, if they get into a ... lab or whatever, at least those principles will have, they'll have the knowledge of the basic principles of science
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> **Nathaniel:** Sure. To me the most important thing is to get a very good, fundamental education in the core sciences and mathematics. If you don't, if you don't have the right tools, you're going to get bypassed somewhere in your career. And if you don't continually update your tools, you're going to get bypassed in your career. So, I guess my perspective is simply to be solidly trained.

Researchers were also expected to communicate their findings truthfully, and to different audiences. This norm was dictated by the value that researchers and science needed to be honest and ethical, and that researchers needed to advance knowledge and make an impact on society. This norm was also mentioned in light of the epistemological beliefs that science was integrated with society, data needed to be repeated by good methods to be validated, and any claim needed to be based on evidence. George believed that researchers needed to be honest in their reporting. Harold believed that changes in technology also required communication by scientists.

> **Harold:** New technologies, new sciences, policies involving resources, all of these things, so people are very bad at that, and we have a very strong responsibility to communicate benefits and risks.

Michael mentioned honest communication and related it as well to the fact that researchers needed to know each other's work.

> **Michael:** Well, one of the things in terms, that I'm trying to make sure that my, my students are aware of is the fact that it is, it is imperative for us to do great scientific work, but it is also very, very important for us to be able to convey the scientific worth that we have done in a clear, concise manner for others to understand and, and, and have an appreciation to what we do ... Well, I mean, if, if, if you're not able to clearly define what you've done, then, then people cannot, you know, of course, follow what you've done, and therefore it's not going to have the impact that, that you wish for it to have. So it is, it is critical.…

Michael's view was echoed by several other participants.

> **Queenie:** And second, if you, if you know something, and if you don't tell people, for example, if you don't publish or if you don't, it, it, it doesn't make sense. If there is no point in learning or doing those things if you don't teach others because some other people, they have a different perspective. Maybe they can use your results in their research and it is more valuable, it makes more sense or useful to the society....

Fred likened the ability to publish as willingness to accept criticism.

> **Fred:** And, you have to, like I said, you have to be able to write to get things out there. You have to be willing to work at that. You have to be willing to accept criticism.

Tim believed that publishing was part of the self-correcting mechanism of science.

> **Tim**: Because, in my mind, science is self-correcting, actually. Ultimately, if you are trying to deceive anyone in science you yourself as a scientist are trying to hurt people. If you discover something new, which is very meaningful, and publish it. If it is true, it will be repeated immediately. If it is not true, you will disappear.

Work on high impact research was another norm that the scientists discussed. This was a norm that could be traced to the value of having an impact on society, which, in turn, arose from the epistemological belief that science and society could not be divorced from each other. Robert believed that scientists were united by the aim of improving the world, whether or not they knew it. Kevin believed that research needed to be for the good of humanity:

> **Kevin:** And, and, I think science should be done that has purpose, that does make a difference in, in the lives of people. You know, science for science's sake is, is one thing but I guess, I'm a more strong believer that science should have a, a purpose, a meaning, a meaningful purpose ... I really feel that it should have a purpose to help society in the long run.

Oliver's statement encapsulates several norms, and ends with the responsibilities of scientists to society:

> **Oliver:** Well, I think the responsibilities of scientists are to, to work as, to be as careful as they can. We all make mistakes, but be honest about what they're doing and then to, to the extent that they can, communicate their results and the importance to society as a whole, and to use their knowledge in ways that benefit society since almost all scientific work is supported in some way by society, you know, we want to give back to society in that way.

The norm was also linked to another norm: that of looking for funding to allow science to proceed, because funding was given only to research that focused on high-impact projects. While some of the participants felt constricted by the demands of funding, others agreed that constraining funding could lead to good science – a belief that could be traced to their epistemological belief that science and society were interlinked.

> **George:** Well, I think if society was perfect, had no problems, then it should be free. But, until then, I think there's value in having the science produce results that can be utilized to solve current social health and other types of problems.

David, however, did not believe in a global science to help people.

> **David:** (pause) I'm not a big fan of the idea that the global science is to better mankind ... Because I feel that's, that, again, is being a little bit too biased towards at least the concept of, you know, humans are superior to everything else. Now, it could be argued that that's the

> way that we should be biased, but, you know, I personally just don't, don't feel that. I prefer that what science should do is be able to answer some very difficult questions.

The participants also believed that disagreements among scientists were the norm. This was expected because knowledge changed (epistemological belief) and scientists needed to be objective and honest (values). Oliver believed that disagreements were part of cutting edge science. George believed that disagreements came because scientists still did not know all the variables in an issue.

> **George**: They have to be critical of other's work as well as their own and consider the options that other people are right and they're wrong ... Or they're both right, which often times isn't the case where you see scientists, you get in the two camps for some particular issue in science when often times they could very well be both right, but it just, for some reason they just get in these little disagreements or spats over interpretations of data or something and maybe there's an outlying variable that neither of them are considering that allows those two ideas to be unified into one, so I think being – the responsibility of scientists to being open to alternatives….

> **Oliver:** Well, and scientists disagreed and disagree on why this and what to do, they disagree on everything. That's the nature of the cutting edge, so what we're doing, people are disagreeing with us, sometimes violently, and it's not because I'm stupid or because they're stupid, just that we haven't done the right things yet. Fifty years from now, my grandchildren, they'll know the answer. They'll know either Grandpa was right or Grandpa was wrong, but we're not going to know that now because yet-to-be-done experiments are yet to be done.

Because discoveries took time and a good deal of basic research, and because science needed to continue advancing knowledge, researchers were also expected to mentor the next generation of scientists. Several participants talked about how mentors had changed their views of research, but they also discussed the importance of mentoring their own students.

> **Bethany**: But it takes a lot of years of knowledge, of studying. One has to have the knowledge base, one has to develop their thinking because one eventually, especially as we progress in science, and we lead lives and we educate young new scientists, uh we have to guide them through uh what feels like a good question or not a good question … that is the judgment that we develop as we progress in this way....

Nathaniel and Larry both believed that their greatest impact was on educating the next generation of scientists so that knowledge would continue to grow.

> **Nathaniel**: ... Education is always extremely important and that's what, most of my focus is on educating graduate students, far more than just doing the science because I'm training graduate students in science. I have um - Three of my former students are now faculty members, with professors elsewhere - and in my field, that's a, that's a lot because I don't train tons and tons of graduate students like many experimentalists do. There's limitations *[sic]* on what training we can do.

> **Larry:** And the, the, my collaborators and my research group, they're more focused on research. They're trying to make their reputations in the research community, which is fine. That's what, that's what's going to fulfill them. But I feel that at this point in my career, I'm putting more effort into teaching because I think that that's where, well, the way I like to think about it is if I can, if I can, you know, launch a few careers by doing a good job of getting people through the introductory physics class, that's a huge reward and likely to have a, a, a greater impact than any paper I publish.

To summarize this section of the results, the participants believed that scientists were expected to be open-minded, think critically, admit their mistakes, carry out careful and systematic work, ask questions and explore, learn and establish a firm knowledge base, communicate their findings truthfully, work on high-impact research, disagree, and mentor the next generation of researchers. These norms were traced to their epistemological beliefs and values.

2. Science dictates that scientists should not manipulate data, lose creativity and critical thinking, plagiarize, or sacrifice integrity for money. To do so would be to destroy one's career and reputation.

The participants were also asked about what was prohibited in science, which prompted answers on the sanctions and punishments in the research arena. The responses that the participants gave can be classified into four major categories: data manipulation, losing creativity and critical thinking, plagiarism, and sacrificing integrity for money. All these sanctions basically translated to lack of honesty and objectivity, two values that are undergirded by the participants' epistemological beliefs. The participants believed that the price of breaking the rules would be a destroyed career and ruined reputation.

The first rule that scientists needed to follow was not to manipulate their data. They were expected not to throw out or falsify their data, or design their experiments to obtain desired results. Several participants provided examples of how this rule was being broken, with Fred calling it a ‘part of scientific culture,’ but which, as several participants pointed out, was also part of the pressure exerted by funding agencies, research institutions, and journal editors.

> **Fred**: And so, we still don’t know which of those is accurate, but, but that is a part of scientific culture to throw out data that doesn’t fit everything because it’s too difficult to explain, and I think that’s something that is dictated now by the pressure to publish and, and, and the hassle of reviewers that makes it difficult.

> **Oliver:** You have to fess, face up and be honest about it, and I would say you should not throw away data. That’s one thing we’re learning. I mean, in this field that I’m working in now a lot of people have thrown away data, turned out to be, it turns out to be a mistake and, but that’s a whole, that’s a part of the methodology which, where your intuition comes in very critically in understanding what data

> you can legitimately regard as an outline and what data you shouldn't be throwing away because you're, you know, you're throwing away an important, what may be an important contribution to science.
>
> **Bethany:** … At Harvard, for example, the professors ... receive tenure only when they reach their full professorship. And to get there it is not, uh not a very easy process and not - the rate of being at that level is very small ... So, people live under very stressful, very competitive environments. Some of them do not have a steady salary, so the salary they have to bring it through their grants. So you hear quite often, especially from places, such high-powered places of how a postdoc um falsified the data and this Nature or Science paper is being retracted. I don't condone it. I did not say it is the right thing to do, but people sometimes become off track. They lose what they, the essence of what they're doing is all about and then they um do things that don't speak, not to their advantage in the long run because you cannot lie about nature.
>
> **Harold**: So, be socially responsible for your work. Be absolutely truthful. I tell, I think one of the things, people get pushed very hard now to produce results. This, we're, we're being buried with metrics and demands all the time to, to produce things. So a lot of people and some labs are very bad that way where, you know, the mentor or mentor, I shouldn't use that word, the professor in charge, will yell and scream at students and, and will only want the results that they want to see rather than the results that are.

Losing creativity and critical thinking, or even losing one's objectivity, was prohibited in science. Patrick, along with Fred, George, and Oliver, also talked about what a lack of objectivity could lead to.

> **Patrick:** And it's crucial. And without that, I mean, there have been dozens and dozens of instances where people lose their objectivity, become more attached to this in sort of an egotistical way and they allow themselves to be drawn into all sorts of problems that way, so objectivity is crucial.

Plagiarism was also prohibited in science. Queenie believed that all research needed to be connected to each other in order to be believable. Not citing previous research, or copying previous research, therefore, was prohibited. Oliver likewise connected plagiarism to lack of honesty, and not giving credit to previous research.

> **Oliver:** Well, you should be completely honest. You should be, have a sense of integrity. You should not, obviously plagiarize. You should always give credit to people that have done work in the field before. I'm a big fan of this, and I really go out of my way to give credit to everybody who's done it before. Sometimes it's painful to acknowledge that somebody has anticipated what you've done, but that's the way the world is.

What many of the participants discussed, however, was how many scientists were sacrificing their integrity in order to be funded. Bethany and Irene believed that they were in research because they wanted to know things, not be famous – a purpose that they believed would lead to dishonesty. Irene went on to talk about how strict funding policies made young researchers turn away from science.

> **Bethany:** ... Uh - We're not to be, we're not uh to find results that will make us famous or successful or anything like that. Just we need to understand, this is what drives us: to understand how nature works and um in a sense it is a sacred type um of a profession if you believe in this sacred uh because we cannot manipulate the results to make them more exciting. They are what they are. We don't hope that the result will turn out in one way or another. It is going to be what it is.

> **Irene:** I think that's, a lot of it dishonest, a lot of it is (laughter) selling yourself which is not the reason that I became a scientist, was to become famous of, of, of or, I just didn't have that in me, so I do find it difficult in these days that no matter what organization you belong to, they want you to write, you know, a paragraph about, you know, what your work is going to do for cancer or for heart disease or for, which of course it may have something to do with that ... It saddens me because I think we're losing a lot of people out of science who just want to do interesting experiments that can't, that, that can't get funding to do those anymore, because they have to work on something that's hotter or more relevant or whatever, and, you know, it's maybe just my opinion, and there are good reasons, you know, to say that people should be working on these more relevant projects, but I don't see it that way.

Ernest admitted his shock at how the current generation of scientists had lost its sense of integrity.

> **Ernest:** And, and, and we've lost it. Our old generation, my generation and older, are appalled. The new generation, well that's my funding source, I'll do anything to get funding. We make bad comments, that sounds like the world's oldest profession and that doesn't (laughter) that doesn't go over real well ... A pure scientist would - is appalled, and the older generation that's retired is appalled. If something's not right and the treatment's not right, the numbers aren't right, the interpretation is completely asinine or people make statements like, 'Don't drink organic milk.' There's a point where you say, you have to speak up and there's principles of scientific integrity, morality and ethics, and science has to be based in reality, has to be ethical, it has to be moral.

Larry's view on the repercussions of such behavior summarizes the views that the participants provided.

> **Larry:** I should tell you that I've got a whole presentation that I've developed over the years that, that deals with ethics in science and, and such. So, sure, I mean, the one, the one phrase that I deliver every time is that science is a set of rules that keep scientists from lying to each other. So, so, if you can't be honest about what you're doing, how you've done it, then there's no foundation to the enterprise of science ... Right? Careers are made on reputations and when that reputation's destroyed, it can't be repaired....

To summarize this section, the participants believed that they should not manipulate data, lose creativity and critical thinking, plagiarize, or sacrifice integrity for money. If they did, they would damage their careers and reputations.

3. Scientists do not always deal well with the world outside the laboratory. They are more introspective and observant, lack political savvy, and struggle to communicate well and relate well to non-scientists. In addition, the real world does not share the values of scientists.

In addition to their views on the norms, values, and rules of science, the participants also shared their views on what they felt were traits unique to scientists. These traits were not necessarily advantageous to researchers, the participants believed, especially when they were called to communicate with the lay public.

Most of the participants believed that scientists were more curious than other people. They also discussed how scientists were, more often than not, quiet, observant, and introverted.

> **Arthur:** Oh I think so, I mean, I think we touched on one earlier which is kind of this whole idea of a natural curiosity. Um - I think some of the other personal characteristics is, you know, scientists, I think in a lot of cases tend to be a little bit, they tend to be people that, you know, that like to do a lot of reading. They like to do, they like to spend some time alone working and reflecting … Not necessarily the, you know, the most outgoing people, not necessarily the life-of-the-party type of people. It's kind of interesting because you look at groups of people and do these, uh um the personality inventories, uh you end up with a lot of people that fit into certain characteristics that, like the ones I just mentioned.

> **Bethany:** ... One has to be, um there are some traits that characterize scientists, you know, they are usually smart and they are usually kind of quiet, they're observant, very observant. Um – they – uh they need time to think. It's not like a, you know, different people have different attributes. You can imagine that a journalist is very smart but loves to talk and loves to synthesize and all of that. Scientists are more, in my estimation, they are more, um, quiet because they do a lot of thinking.

> **Harold:** But the problem is that many scientists are not naturally skilled, so a lot of people who go into science do so because they're shy, quiet people who don't, you know, like big crowds and interacting with large groups and all that kind of stuff and I think if you do the Briggs-Myers personality test or whatever, on scientists you would generally come up with INTPs or INTJs or whatever or INT ... I forgot what they are, but I just did one not too long ago, so that's how I sort of remember. And most scientists are like that, introverted, uh uh quiet types who are not necessarily comfortable or good at speaking in front of large groups.

The participants, like Harold, admitted that there were several traits that kept scientists from communicating well with the lay public. Patrick believed that scientists were often “caught up in the vagaries of the data” and therefore did not know how comfort people. David believed that scientists often mistakenly thought that the world lived in the scientific method, while Fred thought that scientists had been too used to working in the academic environment.

> **David:** So it’s, it’s, it’s easy to get caught up in just thinking of the whole world using your so called scientific method without realizing that the world doesn’t live, you know, in the scientific method, so, seeing it, so at least for me, you know, there are things like that that I do realize that people are people, and so I have to kind of keep that in mind when I’m dealing with them.

> **Fred:** I think that’s a big problem. An error that we’ve made is that we were so used to being in an academic environment, many of us and communicating through public communications and technical scientific jargon, in many cases, that we, and sometimes to us the, the benefits of certain things are so obvious that we don’t even need to explain them, but to other people it’s not quite so obvious, you know?

Harold, however, believed that many scientists became “protective” of their work because the rest of the world did not share the values of science.

> **Harold:** It’s also, sometimes it is a little bit protective because we realize that we’re in a world where people have that same sense of values. When, when, when you go out on the, that’s why a lot of scientists will not go out and talk in public because they know that their values are not necessarily shared by the audience ... Because most people don’t care about ideas. They don’t care about these passions for learning and whatever in the ‘real world’ ... so yeah, that’s how it is for scientists, you know, we, we, we are, sometimes we don’t feel much connection to the ‘real world’ out there. They don’t share our values. They don’t share our passions. It’s not pleasant being out there, so there is a, there is an element that makes us want to stay in our ivory tower because at least we can discuss ... and argue about ideas that everybody else is just worried about the next soap opera show or whatever that we could care less about.

To Nathaniel, however, introspectiveness and unwillingness to communicate were working against success.

> **Nathaniel:** In this day and age, if you're going to do science, you've got to be aggressive, you've got to be competitive. If you're too introverted, too laid back, you're just going to have a hard time competing in the long run, no matter how good you are.

4. For participants, their research is a hobby, not a job.

Despite their difficulties with funding and other struggles that they had to face in science, the participants believed that to succeed in science, one had to adopt it as a hobby. Bethany believed that all scientists were simply "attracted to the process of discovery". Irene believed that science was a lifestyle and not simply a job. Tim and Michael believed that researchers needed to make their research a hobby in order to be successful and sustain their work.

> **Tim:** ... but one thing that is very important that you want to be able to really think about, that you have some element of hobby in that. If it's a hobby, then you can sustain the repeated failures, which you always see in science. Science is not that you design an experiment and it will work tomorrow, and then you manipulate an equation. You will get stuck after four steps. So, I think this is important for scientist to have their hobbies to be thinking about it and then they will find a solution.

> **Michael:** So, that's the basic thing and, and I, I tell them to have a passion for the job, the job needs to be your hobby, and your hobby needs to be your job ... You know, if, if that, if that's the way you approach it then you'll be successful. And that's the way we do our research. I, I, tell my sponsors, you know, we have once a year meeting here with them. We go out to dinner and then we have a one-day full presentation discussion about work and I, I tell them that I, we feel as though we are professional athletes. Somebody who pays us and we play. And, and that's, that's the way we do it.

This likening of science to play was echoed by Harold:

> **Harold:** And if they knew what it was, I mean, we, we joke about that, we say, 'Don't tell anybody. I'm having fun! They're paying me for this! And I have all these marvelous toys in the lab that I get to play with!' You know, I can't imagine why somebody wouldn't want to be a scientist ... they don't understand the supreme sublime pleasures that come out of that work that are far beyond what somebody could pay you for.

To summarize the last two subsections of the discussion, the participants believed that they often had common character traits that distinguished them from other professionals. These character traits could stand in the way of success in science. However, the participants also believed that their work was not a job, but a hobby and a lifestyle.

5. The science that researchers learned in school is very different from how science is practiced

The participants were asked about science or engineering as they had learned it in school. Many of the participants believed that the science or engineering that they had learned in school had been based on facts, and not theory. They did not learn how the facts could be applied in the real world. Christopher, in particular, called school science a “layman's appreciation” of the scientific field because science was often portrayed as absolute. Michael echoed his “mechanic's point of view” in his own statement about how his point of view changed as a professional in engineering.

> **Christopher:** ... you don’t have a full appreciation for the … see the theory in practice of science until you are exposed to the ideas and the basis for the theory and practice of science. Why we do things a certain way. Before you have that exposure you think of science as more of a, you don’t have, let’s see, how do I want to put this? You just have a layman’s appreciation for it ... And it seems very distant to you, you know, it’s like, okay, scientists do these things and there and you picture these guys in lab coats somewhere, you know, in some laboratory or clinical setting or whatever. But as you are exposed to more ideas, I think, and more - become more engaged in doing science and through that gain an appreciation for why it’s done the way it’s done, until you have that exposure and that experience, you could never really fully appreciate it. It’s just like anything else, right? Just like if you were, yeah, I own a car and I have an appreciation for the complexities of what’s under the hood of that car, but not like my mechanic does, right?

> **Michael:** ... What we do now is a scientific point of view of the problem, so it is, it is very, very different. Yeah ... Well, I mean, now, we don't look at, you know, the, when, when you're working on a car you, you, you don't care about how the details of, and what went through the process of coming up with a design that works. You know, if it's broken, you replace it. You know, if, you don't care. You don't care. But now, what we do is that, why did it break, and what was the process, and how can we improve that to make it last longer, run more efficient and do the better job....

Like Christopher and Michael, the rest of the scientists talked about how further training in science allowed them to see the context of work and appreciate its abstractions. They also realized that science changed and was dynamic, compared with the layman's view of a science that was absolute. For instance, Arthur saw it as a "natural" progression away from the "black box of science".

> **Arthur:** ... Because, you know, you spend your time focusing and then at the end of the Ph.D. program all of a sudden you start getting pulled in all these directions and you start to worry about how everything connects and then you realize that it's not really, um you're not really only zooming but you're also trying to understand everything in con - context of all the other disciplines of science.

Fred slowly learned that science could only suggest, and never conclude. Like Fred, Oliver found that textbook knowledge was simple, and that in real life, not everything was known.

> **Oliver:** ... you're taught in textbooks a lot of things because textbook tries to simplify life and can't get into the details. In real life, the extent to which certain facts are actually facts and known are quite different and, and the interaction, especially in physics between theory and , is very different from the way it's portrayed in textbooks, and that's one of the things we're learning about life when you become a real scientist.

He went on to talk about how the scientific method is taught in schools.

> **Oliver:** ... scientists study some phenomenon and propose a theory, and then some other guys test it and verify it or not, so you believe a theory if experiments support it. What is not clear, and you asked

> this question, what's, how does science work in real life as opposed to what you learn in school? Sometimes it works backwards.

To summarize this section of the results, the participants had their own culture, with norms and values undergirded by their epistemological beliefs. They had traits common to them, and many of them believed that scientific work was a hobby more than a job. They also believed that the science that they had been taught in school was very different from the science that they practiced as professionals.

How does the surrounding culture of the researchers affect their work?

The participants were asked to talk about their native culture and how it affected their work. There was a variety of responses to the question, and the participants mentioned cultural elements that both hampered and encouraged scientific work and science communication. Their responses will be presented in this section under various generalizations that were generated from the data, along with representative quotes and a discussion of the quotes.

Four of the participants were not originally from the United States, but they had lived in the U.S. for at least a decade prior to being interviewed. These participants were also asked to talk about the cultures in which they had been raised.

In general, the participants believed that scientists would have different cultures depending on their home departments, profession, and location, although for some, "scientists are more like each other than their own countrymen," as Harold said earlier. What the participants agreed on, however, was that science would always be part of society, and would always therefore have to serve or interact with society in some way. This need to interact with and therefore be of service to society also led to the various effects that the participants' surrounding culture had on their work.

1. Science may need resources, but funding pressures have forced some researchers to work based on project impact, disregard negative results, and compromise their integrity.

As already mentioned in the previous section, many of the participants felt as though they were being constrained by funding policies. They believed that funding and publishing priorities were given to research that showed a statistically significant result. To Arthur and Patrick, such funding policies were “tragic”; to Patrick, it simply had to be dealt with because he had no other choice:

> **Patrick:** It could be nothing more than the fact that there’s some money out there that NSF is putting out if you do research in a given area. Okay. So here’s some money that’s available. What can I do that might be interesting to the research review panels who want to look at my proposal? So then you try to come up with something that’s sort of interesting and new, something that you can do and develop a proposal from there. It’s sort of a weird way to go about it but it’s what drives up an awful lot of the research these days.

Irene did not want to give in to the funding policy, especially if researchers had no passion for a project.

> **Irene:** But what is a person supposed to do, look at this and then change the whole focus of their, of their science to address this question just so they can get the $200,000? Does this make sense? No. This is a waste of money. This is a waste of money. So, I, I don’t know. And they perceive of this, someone is perceiving of this as a need. We need to have more people working in this area, therefore we’re going to put out this, and, but that’s not the way science gets done, in my opinion. That person that’s designed that project, to look at that question does not have any passion for that project, has no passion for that topic. They’re just doing it to get the money. I don’t, I don’t think that’s a good thing. And it happens more and more and more.

2. Politics can drive funding and set the research agenda, but it can also focus research so that research has impact.

The participants believed that politics played heavily into funding, for which many of the participants expressed resentment. To Larry, for instance, science communication needed to be done before politicians, who had no science training, could take over. This lack of control was also expressed by Robert, who saw how politics influenced funding; and Tim, who believed that politics also controlled risk communication.

> **Larry:** When its, when it's appropriate, scientists should, I mean, we're, we're, we're scientists. We're also citizens so why shouldn't we participate in a public discussion as well? So, you know, nuclear waste. It's very important that scientists speak out about the relative merits of 1 alternative versus another for dealing with - otherwise it's going to be left to people who are not experts, and, I mean, this is part of, part of the real problem in, in, in congress. Very few congressmen are scientists.

> **Robert:** But right now, because politicians are the ones in control of the, the, the money mostly, and also because you have these businesses that are trying to satisfy their investors … that are non-scientists and, and, and because you have all the other things, scientists right now have very little control, even though they know that they could solve these problems, they have very little control because the way society is, they need funding, and so there's only a small amount of pot for the funding and the people who are controlling what the funding is used for has, it's all political. So, that, that means that there's a huge bottleneck in, in, in this issue.

Oliver also believed that politicians abused the findings of science for their own political purposes.

> **Oliver:** Well, we've seen certainly in the Bush administration, you know, using apparently either distorting science or putting pressure on scientists to say things that are, which comport with whatever political philosophy, you know, people believe in. I think that it's certainly clear that the government still use science one way or

> another to support views or, or let's say, try to deter people from saying things which go against whatever their administration says.

Despite these complaints, however, some of the scientists still believed that politics had its uses. For instance, good science could arise from political issues, as Arthur said.

> **Arthur:** ... On the other hand, I mean, I think, you know, certainly some of these political decisions have forced us to um to develop sound science much more quickly and really move things off center so I think back a long time, think back to the 1960s and, and, and the Space Age where really, you know, many, many of the discoveries that were, you know, developments in - in computational science, you know, food preservation, all of those kinds of things, that were driven by the space race which was really just a political, um entirely a political situation to, between the U.S. and the Soviet Union to land a man on the moon.

Some of the participants also believed that good political regulation of funding could allow research to be better focused. For instance, George believed that controlled funding could allow science to be redirected to projects that could help more people. Tim, Bethany, and Christopher expressed their agreement in various ways.

> **Tim:** ... Economic constraints, unlimited money will basically lead to more horizontal research. So we need to do more vertical research because we do not want to have identical systems, and in a system you want a system at such a level that you should be solving more problems.

> **Bethany**: ... so NIH stands for National Institute of Health, and the mission of NIH is to improve the quality of health of the people ... So it is understandable when the money is less to move away from the basic discovery projects and to focus primarily on these projects that have high impact to cure something.

> **Christopher:** I think it's, that's an excellent question, by the way. There's a need for, for us to focus funding in certain areas of science because there are certain societal problems that we need to solve, right? If, if it, if there wasn't the funding available to go after problems like global climate change, alternative fuels, etc. which is

> driven by politics, I'm not sure anybody would really be all that interested in doing it or there would be maybe fewer people that would be doing that. So there's a need for that, because it helps us to move forward as a society.

However, Christopher also believed that funding was also needed for research that was based on "pure inquiry":

> **Christopher:** But on the other hand, I think there is a need, there still should be room in there for just pure inquiry. Just asking questions, why does it work like, does the universe work like this, you know, trying to understand it. And those aren't necessarily anything that have direct impact on anybody's lives, but I just can't help but think that, you know, our, our lives and our existence is made much richer by having that sort of inquiry, right?

3. American culture emphasizes creativity and recovery from failure, and these features are sometimes not found in other cultures.

When asked about the American culture, the participants provided a variety of answers on various traits and trends that they had observed. For instance, Queenie, a native of a Western Asian country, thought that there were no politics in academic departments in the United States. This was something that she appreciated compared with the learning environment in her native country. Ernest believed that agricultural researchers in other countries were more concerned about "people starving," while American researchers were more concerned with efficiently using various resources.

To Steven and George, the American culture stressed creativity, which they believed was important to scientific work:

> **Steven:** I definitely think that there is, I don't know if this is, it's an American thing or it's sort of a western thing, but if you compare the kind of training and the, and the way people approach problems … and this, I don't know this for a fact, but it's sort of the way I feel, there's a difference in sort of the brute force, overwhelm-the-

> problem approach and the more creative, try to get a nice solution and think about it deeply and I tend to think that the, in the sort of American way of training students, and it's not just Americans, it's other countries too that have the same sort of philosophy that tends to promote sort of creativity over, you know, overwhelm it with just like, you know, brute force.

> **George:** I think my background as an American and my background in, in, with family and things, it always emphasized being creative ... And that's something that I think is very valuable in science. It helps you solve problems by testing other approaches at a more faster [*sic*] rate than often times I've found with students and others from other countries where that isn't as emphasized in education. So, that's one of the, you know, there's a lot of emphasis on how, you know, I hear a lot about, in the news anyways, how Americans don't score as well on exams compared to the world and our education system is falling behind. But then again, at the higher institution level we have the best institutions in the entire world.

To Jessica, the American culture stressed recovery from failure, which she thought was not as apparent in other cultures.

> **Jessica:** ... I do see the pick yourself up by the boot straps and move on and being able to face failure. That's the biggest fear that I have with some of the Asian students that I have is not being able to face failure because they've never failed.

On the other hand, Jessica later expressed that American society did not place a great stress on education. Arthur and Christopher were also among several scientists who believed that the skepticism of the general public regarding science was affecting how researchers worked.

> **Arthur:**I think one of the things we have valued, we, I think we have valued our … I think as a culture Americans have tended to value science until fairly, until very recently. You know, I think we still value science but there's a little bit more skepticism I think in recent years, and, um you know, I suppose that affects how we approach science to some degree.

Some of the participants also compared how various cultures interacted or did science, and how these cultural nuances affected their work. As already mentioned earlier, participants thought that international students were generally at a disadvantage because their English was not as polished. Fred believed that researchers from the Netherlands and Germany tended to be very direct and blunt, which could lead to difficulties in interacting with them. Fred also went on to talk about the Asian culture, which he perceived as submissive to bosses, even if the boss was wrong. He believed this trait could curtail scientific research.

> **Fred:** And that can be another problem where you have, uh I've interacted with people from several other countries where they don't want to tell you that you're wrong, and especially, some Asian countries, for example, Korea and this and that, they, they, they're taught that the senior person is always to be respected and is always right basically, and so they won't contradict you sometimes when you're wrong, and I don't expect that everything I say is going to right. I'd like it if it was, but I realize that a lot of times it isn't, and, and I, and I want someone, if I'm going the wrong way, not to agree with me but to say, 'Oh no, that's, I think that's wrong,' you know?

Jessica also talked about her perceptions on the Asian culture in her interview, and believed that some Asian cultures were not prepared for failing in certain ways in the same way that the American culture had taught its members.

> **Jessica:** ... I mean, that's kind of sometimes the difference between what I see with Asian people in science and Americans in science. We tend to be a little bit too full of ourselves, too boastful. I hope I don't fall into this category. And I'm being generic. And, and kind of diving in without taking everything into account first, and I've been, I've certainly done some of that....But I don't see Asians as being quite that way, and I see them as being real truly good work horses, intellectually capable, but also sometimes to a fault and this would be a cultural distinction in that wanting to succeed so much that they might twist and bend because they felt they weren't going to succeed.

4. Mass media often misinterpret and misrepresent both science and the lay public, which leads to confusion and ignorance about scientific facts.

Several participants also discussed what they felt about the mass media. In general, they believed that the media misinterpreted and misrepresented science and the lay public. To Robert, this led to low opinions of science and ignorance in the public because non-scientists learned from TV after they left school:

> **Robert:** After they were in high school or they're in college, they learn from TV. And so when you're looking at people about what they're, what they think is most important, and they have all these surveys and things like that you hear about, they put science very low or they don't even ask about science in most of the time.

To the participants like Patrick, Irene, and Nathaniel, the media would often twist the facts or misuse them. Arthur believed that the media was confusing the public by not presenting facts.

> **Irene:** That's what they, and you, whenever you communicate with someone who is in the media, you run the risk they will misconstrue, not, not maliciously, but for their own purposes of getting attention, they will magnify, they will misrepresent what you do. So you've got to be very careful about what you say and how you say it.

> **Nathaniel:** Misuse of facts ... And, in irrational fashion. And then because you're making some assumption that's not, that's not reasonable and- It's usually based on, well, I see people make assumptions that are essentially not verifiable, and then they draw conclusions based on their assumptions that they've made but not understandable, they're not verifiable, then that's, that's, really disheartening - and I see that all the, you see that when you watch the news, you see it all the time.

> **Arthur:** ... People are spending dollars that they don't have to buy organic produce for example when there's no advantage and we're not communicating that ... Um, and I think, you know, if people want, if people have disposable income and want to buy organic um because it makes them feel better about themselves, that's fine, but let's not confuse people by telling them that organic or conventionally-produced products are different. They're not.

To Robert, the media was not as careful with its claims the way that scientists were. He provided the example of survey results before an election, and how such claims could sway votes in any direction because they misused statistics.

> **Robert:** And we're really careful with our claims, right? I've seen other people like for example, if I watched the news, and they're having all this data coming in, and they're sort of like abusing what the data reveals. Like, for example, they'll have these, these politicians running for office and they're neck and neck, and then they'll say, you know, one has, like 49% and the other has, you know, I don't know, 47% and so this one's in the lead but then all of a sudden in little tiny writing they say plus or minus 5%, and whenever they use that they say, this person's in the lead and if, if, if, if they wouldn't put the uncertainty there you can't make that claim about which one's in the lead or not, but what happens is because they say this one's in the lead, then other people out there who may not really know about the candidate, they'll view TV and say, oh, that's the winning candidate right there.

Harold believed that the media abused numbers in general in its bid to create a sense of "balance". He provided his own example as he discussed the issue of disagreements about global warming

> **Harold:** ... we have now a society where we have news that is, people try, they think that they are presenting balanced news by presenting 1 person for, 1 person against. And, and typically, particularly in a 'scientific sense,' 99 out of 100 scientists may believe one way and strongly believe and think they've got it pretty well figured out and then they'll trot out that 1 person in 100 who very frankly is considered a bit of a kook by the other 99 and trot them out and then try to give them as if they have equal importance, and I say if you're going to do that, then what you've got to do is hang a big number up behind each person and say, 'Okay, this person, 99% of educated scientists in this field agree with this person and 1 in 100 believe this person,' and give, give the public a front, because that's what the public doesn't get right now. They don't get a sense of, of what, what scientists really believe, and there's a lot of things. We have a lot of this in terms of, of, you know, global warming, okay?

Harold also believed that communication, in general, was based on pushing emotional buttons. Participants such Jessica agreed, and also added that the media were driven by hysteria:

> **Jessica:** Hysteria sort of driven ... And unfortunately, it seems like there's a lot of that, that we are just driven, the public is driven, is that what they think is interesting to us? And that, that we won't respond unless it, you know, really gets our attention or scares us half to death or is that their motivation?

Jessica continued by discussing how the media underestimated how much people could understand about science and risk. The rest of the participants also believed that the public readily believed the media portrayal of scientists as crazy or evil, and therefore had a low opinion of scientists and scientific work

> **George:** ... I think overall the public views engineers and scientists very favorably ... Because they build things that you use, like iPhones and bridges and computers and information technology and everything like that. But I think that sometimes there's an opinion of research scientists as being the kind of geeky, shady character who has always got frazzled hair and, and I think part of that just comes from the portrayal of scientists in movies where, I mean, almost every movie that portrays scientists portrays them as either that type or completely evil ... And wanting to just take over the world or destroy it in some fashion. And so, I think that shapes people's impression of scientists more than just about anything is some of those caricatures.

> **Harold:** We're really trying to do the right thing, and yet we get vilified or, or, you know, the, the public perception of scientists is either a Christopher Lloyd, Back to the Future mad scientist, and I tell people that we're not mad scientists, most of us are pretty happy. And we're not crazy. We're pretty normal people. It's, it's the perception is, so far most people have never met a real scientist. This is a university town, but that's really true, and they have no idea, I mean, these are like, almost like aliens from, from another, from another planet in the way we think and do things....

5. The public does not understand science and scientists because of poor media reporting

The participants also talked about what they believed the public perception of science was. Larry believed that relative to politicians, scientists were in good standing with the public. Nathaniel agreed on the basis that the public knew that scientists had contributed greatly to progress. However, he also believed that people were suspicious of scientists, and scientists would sometimes be regarded as crazy.

Robert, on the other hand, believed that the public lacked scientific thinking and did not understand exactly what science and scientists did, and how science had benefited humanity. Harold and Steven agreed with him, and Steven even expounded on how people did not know the difference between science and engineering.

> **Robert:** Yeah, so, so the thing is, it is, is like, they may not truly understand what the impact is or the benefit is, of, of, of science. For, for example, like, there's lots *[sic]* of people who donate to, to these certain causes, right? Like, for example, let's say, they'll donate to, I don't know, some, some cause to like, to feed a poor country.

> **Harold:** I mean, they kind of know what, they think they know at least what a doctor does or a lawyer does or a businessman or fireman or policeman, but things like that, but they really don't have an idea of what a scientist does all day, so that's, that's the first problem, is just straight ignorance ... And I think that's particularly important because, as I said, otherwise they don't really know, and they get up through high school and we wonder why they don't pick careers in science because … They have no idea what a scientist does.

> **Steven:** I think if you were to ask someone about engineering they'd think of train engineer or someone who probably, probably, you know, tinkers with, like, computers or, you know, or ham radios or something. I don't think, in the United States at least, that there's much perception at all, because I believe that if you were to take someone who's actually an engineer and they were to talk in the press, they would be categorized as a scientist.

Like Robert and Harold, some of the participants believed that the public was ignorant about science. Kevin shared that he had read that people who served on juries were typically at a 7th or 8th grade level of science, which meant that researchers who testified in courts also needed to communicate better with them.

Not only was the public ignorant about science, but it was also ignorant about the nature of science. In particular, participants thought that the public did not understand that science did not always have all the answers about certain issues. This lack of understanding, as well as the complexity of science, Arthur and David believed, led to a lack of trust in scientists in general.

> **Arthur:** There may be a couple of reasons for that. I think we, I just talked about one of those being just the complexity of science, so it's more and more difficult for people to understand because they're farther and farther removed from, from, from current science, okay? Um - But number two, I think there's a skepticism because more and more scientific discovery is um, is driven by um for-profit business and not by public supported research.

> **David:** Yeah, yeah. Like I say, this is just the USA Today poll that came out maybe the last week or so. So, you know, like in general I think people really don't trust scientists, but I think a lot of that's because people don't understand what scientists do. Now, I don't know if that's because people got scared off when they were, you know, taking classes in college or, you know, in high school or what have you, but ironically science is what people use on a daily basis. They just really don't want to think that this is what they're using.

Christopher and Oliver believed that the public was anti-science and anti-intellectual.

> **Christopher: ...** but there seems to be some disdain for scientists in our society ... There seems to be a, an anti-intellectualism that has gotten out of control. You know, for a long time in American society intellectuals had a place, they were encouraged. They had impact and people listened to them and took, took their ideas and built on them, and that's why American culture has been very successful ... That's part of the reason, okay? There are many other things, of

> course, luck being part of it. But, you know, our society up, you know, at least in the United States, our society up to this point, we have grown, we have benefited from the input of intellectuals and rigor and thought and careful scrutiny of ideas.
>
> **Oliver:** Well, I just read a survey. Basically people have a positive view of scientists in general, although not as positive as it was when I started out. When I started out, people had a much higher view of science. I mean, science was much more highly regarded. Somehow or other the country's gotten turned around and there's sort of an anti-intellectual atmosphere in certain parts of the country, so, including scientists.

Christopher believed that the anti-intellectual climate could be stopped by having better politicians. The current political climate, he thought, was anti-intellectual and was therefore allowing people to behave as such.

> **Christopher:** ... And so they are fostering this disdain for intellectuals, people who think, and they benefit from it. That's what I think. I can't imagine, why else would it happen? You know, what else could be at the core of this unless you have something, you have a serious problem with knowledge and understanding? If knowledge and understanding are your enemy, then you are going to foster that sort of climate, the anti-intellectual climate, so I can't help but think that if you're fostering an anti-intellectual climate, knowledge and understanding must be your enemies. That's what I think.

6. Religion can inspire questions or make scientists avoid certain research problems, but it cannot guide scientific work and should not affect individual scientists.

The participants likewise provided varying viewpoints on the subject of religion. In general, however, a majority of the participants believed that religion was a personal choice and did not necessarily affect what they did in science. Ernest, for instance, believed that many agricultural scientists were Christians, but did not allow religion to drive or change their work.

For Irene, religion might be the root of her ethical values.

> **Irene:** I, I avoid experiments that in my mind I don't feel comfortable with. I wouldn't want to do clinical experiments with people. I don't know what that means. I don't know if that means that I'm, I just, I just don't want to do that kind of stuff. Do I think that people should do it? Sure. I, I, I look at the data. I think it's, you know, wonderful. But do I personally want to do it? No. So, you know, those are the, you know, am I interested in the whole stem cell thing and making embryos and, no. I just have no interest in that, and I don't know, again, whether it's something in my religious background, perhaps, or in my ethical upbringing that says you don't mess with that kind of stuff. This is like, you know, I, it's interesting but I just, you know, I don't want to personally do it, so yeah. Would I come out and speak against someone who's doing it? No. That's their business.

For many of the participants, religion did not make one a better, worse, or different scientist. George, for instance, was a member of a campus religious group. He also discussed how Francis Collins, director of the NIH, is a Christian.

> **George:** ... I don't think being religious makes one a better or worst scientist, so, and in that sense I didn't think any of the discussion of scientists had anything to do with that. I certainly don't think it makes me any different of a scientist than somebody else. I mean, the director of NIH is a, is a Christian. He wrote books on it ... You know, he's a, he's one of the highest respected scientists there is in the country in biology ... And, so, I think it's something that is often politicized and made a big deal, and I think there are some scientists who are very vocal about it. What I find it odd often times is that the scientists who are the most vocal about these specific issues, evolution, are not biologists, both for and against it. The strongest people, the people with the strongest opinions that I've known about the use and teaching of evolution don't study biology at all. They study materials or they study physics of particles, but yet they have these super strong dogmatic ideas about what everybody else should be learning, and then you talk to biologists, and myself included and others, is there's a few examples of where these people with strong opinions but other people are just not as heated in that, in that question.

For some of the participants, however, religion could affect scientific work in various ways. For instance, Robert found early in his childhood that prayers did not get him what he wanted; but if he worked hard in science, then he could solve problems on his own. Fred related a story of a colleague who was not allowed to teach because he did not believe in evolution. Queenie, a devout Muslim, revealed that scientists were held in high regard in Islam:

> **Queenie:** Did, yes, I'm, I'm Muslim and in, in Islam science is very important because it is, it is a form of God and understanding God, and I think all of this has a meaning, so it affects my, my work, the understanding of God or why we are here and why we are doing these things that are very, or those kind of things and the unifying feature of science is, is a kind of, a form of God, maybe. Yeah, those kind of things. So, people doing science is very, very valuable and very respected in Islam, and it is, it is like, like a prophet, so some kind of, maybe it is something, exaggerated – or I exaggerate it, but it is very valuable, people doing science. It didn't affect my decision that way, but I think what I do must have some meaning in life, and since it is, it should be beneficial to humanity, and it should be useful to other people. These are aspects coming from religion, so this is, that is what is Islam is, it's what you do must be beneficial to others ... And it should have a meaning because in the end we are going to be asked what we did and how does it affect it, so better we spend our time effectively for all.

Fred's colleague was religious, and Fred anticipated that there might be troubles due to religion-related issues.

> **Fred:** And so, and I'm not, and so, but we work very well together. He doesn't try to convince me to go to church or whatever, and I don't try to convince him to stop doing what he's doing. I respect that he's, he's religious and when we go, and when we go places, he always has to pray before every meal and all that kind of stuff, so I go with him I just go and I wait. It's not a big issue. He hasn't tried to, he gets very nervous if we start talking about evolutionary things in the paper ... But anyway, so when I'm writing a paper on evolution, that has an evolutionary aspect, it's, if I had a religious coauthor and he said, 'No, we can't write that,' that would be a problem. So far, he hasn't done that and, and I, and I do write it a little bit, and I guess it has affected me somewhat. I do write it, I keep that in mind when I'm writing something where he's the coauthor I make sure I don't have anything that's going to offend him in any way.

Jessica shared how she believed religion was affecting scientific research in general, and stem cell research in particular:

> **Jessica:** And my students from Brazil said, 'Well, you know, we just love that in Brazil because now we can go off and do all the stem cell research while all of you in America just fall behind.' And, and, you know, it's just a, just a statement, but there's a lot of fact in that statement, and, and painful fact too. So, tangentially I think that it, sometimes, you know, what I say about religion is, if you don't want science in religion then don't try to put religion in science, so stay out of science. I'm not going into your church and trying to force science on you, and I don't expect them to come into science and force it on me, and that's the way I feel about it, period.

Patrick, on the other hand, believed that any religion-guided research was also misguided. Patrick, Nathaniel, and Fred saw religion and science as opposites. Nathaniel also stated that being a creationist was antithetical to being a scientist.

> **Patrick:** No, and it shouldn't. I mean, that's, that's part of the objectivity. I mean, there, there are people, no, it can't. I mean, any more than anything else that I believe in or some sort of, I mean, the reason why they call religion faith is because there's not necessarily a tremendous amount of evidence for it, and that's what faith is all about. It's not what science is all about. If you're, if you're doing, you know, some sort of research to prove that, you know, that the great flood was associated with Noah's ark, was responsible for the carving out of the Grand Canyon, well, that's not, that's not really research. I mean, you know, you've biased yourself, your hypotheses are going to be all skewed, you don't really even have a hypothesis, you probably won't accept whatever the results are, and it will keep moving on in different directions trying to prove some aspect of this, which is, you know, if it, if it wasn't being driven by religion it would be considered to be completely and totally unethical. When it's being driven by religion it's just considered to be misguided.

> **Fred:** I mean, the main anti-science out there right now is religion and maybe politics, but, but, and not that religion is anti-science necessarily, but it's different. There it's, it's faith. You either believe something, you either believe it or you don't. And you don't care about the facts, and even if someone has facts proving it wrong or saying that it's wrong, you don't believe it anyway, so that's, that's not science. That's, that's the opposite of it. And that's fine.

However, David believed that science was its own form of faith because it relied on the work of scientists who had gone before.

> **David:** ... the basic faith that scientists have is that there exists an answer to your question. You know, if, if, if you don't even believe that, then that would just stop you from asking any questions whatsoever. I think then, then a lot of scientists might say that they would base a lot of, say, their theories or that their conclusions on things that they've learned from other people. But then it comes down to that you really have to have faith that the people before you did all of this correctly ... There's a lot of things that we accept on faith that we might just say is science but it's not, not really right. You know - You're really just accepting it on faith and you have to go from there ... So in, in some sense, you know, scientists and mathematicians have their so called religion, you know, you can call them, like, set of axioms or what have you, but, you know, certain things that, that we just accept to be true. We might question them from time to time but we have to all start from somewhere in order to go to the next step.

What does it mean to be a civic researcher?

In this portion of deductive analysis, the researcher read through the data and highlighted portions relative to typologies that addressed Trench's (2008) classification of science communication, Swidler's (1986) culture-as-toolbox model, and Lam's (2010) boundary-setting framework. These typologies were presented earlier in the Methods section of this document, and are detailed in Appendix G. When the data were completely coded using the typologies, the researcher summarized the ideas under each typology. The researcher looked for overarching within the summaries of the typologies. These overarching themes were then used to recode the already marked data.

These overarching themes were then used to formulate generalizations, which were used to answer the research questions. These generalizations are presented below, along with quotes from the participants and a discussion of the quotes in context.

What science communication model do the researchers follow?

The participants in this phase of the study had varying degrees of experiences and interaction with the mass media and the lay public. Bethany talks about her research to visitors at the research center in which she works. Fred works with a government agency that is concerned about commitment to science communication, and two weeks prior to the interview had been at a conference where bench scientists had expressed concern over how agriculture was being portrayed in the mass media. Harold had been carrying out public outreach for over a decade, and talked to the public at different venues about his research. Kevin was regularly called on to testify in court as an expert witness in forensics. Larry is involved in a program that aims to change physics education at the tertiary level. Oliver, Robert, and Tim have been interviewed by the mass media regarding their research.

Based on the tallies of their answers to science communication and risk communication questions (Table 4.7) as well as their detailed responses elsewhere in the interview, the participants in this study are following a communication format consistent with the dissemination model of science communication.

On the whole, the participants believed that science was the source of knowledge, and was responsible for serving society because it had contributed to progress. According to many of the participants, science was responsible for much of the useful knowledge that had been instrumental in mankind's progress. While participants such as Christopher and David believed that there needed to be room for pure inquiry in science, they nevertheless acknowledged that scientific inquiry had contributed a great deal to understanding various problems. Tim and Robert believed that science was there to create new knowledge.

> **Tim:** I think if we do not have knowledge, we cannot , this world will look the way it was still 20 years ago, forty years ago. Where we were sleeping on tables, drinking dirty water, for 400 years. They say until 1901, the average human lived to 40 years of age, because we did not have any sanitation. Well, sanitation came, not because of engineers, it is because of biologist and scientists who played an important part.

> **Robert:** Well, they have a huge responsibility because if you look around us, from everything, like even the chairs we sit in, the floor we walk on, the clothes we wear, the books we read, all those things has – has science all in it, you know? Engineering, you know, people always say, you know, if it wasn't for scientists, engineers we'd be living in caves, and that's, and that's pretty true, I mean, so, even people who are not into science, they use it. They, they benefit from it all the time.

Today's science, the participants acknowledged, was complex, and the lay public was far removed from it. Many of the participants used words such as "ignorance," "don't know," or "lack knowledge." To Ernest, however, the public was still educated in other fields, but was "out there in left field" when it came to the natural sciences. Robert believed that the public learned from TV and therefore believed in what the mass media said. To Fred, science was receiving a negative backlash in the media because people were not educated and did not understand science well enough. These views of the authority of science and the ignorance of the lay public are both consistent with the dissemination model of science communication.

> **Fred:** ... Part of the reason for negative reaction is for genetically modified foods, for example, in my opinion, is due to lack of education ... But that message doesn't get out there and instead they, 'Oh, it's Frankenfoods,' it's this and that, you know, people manage to use these scare tactics that can overwhelm logic but they don't, it's not logic because people don't have enough understanding and they don't

> have the background information, so education is certainly one benefit of it that needs to come out of it

Scientists, on the other hand, practiced science and therefore knew it intimately. Therefore, they were tasked to communicate with the lay public. Many of the participants believed that simple language "at the level of the audience" was needed to make communication better. The simplification of language as a tool of understanding is also consistent with belief in the dissemination model of science communication.

The proposed content of the communication, however, was not only fact. Robert believed the public also needed to know what the big questions were in science, and Oliver believed the public needed to see other aspects of the nature of scientific work as well.

> **Oliver:** ... but it would be to honestly communicate ideas to the public in a way, hopefully in a way that they understand, not only the ideas but the ideas, the excitement, and clearly what the implications are of whatever is being communicated....

The job of the public, the participants believed, was to understand and appreciate science. To David, this also meant that the public needed to be comfortable with talking about science the way that scientists did.

> **Bethany:** ... On the other hand I believe that the public has a responsibility to educate themselves, to appreciate all the new developments because if they don't do that the rate of gains in technology and in science is so fast that the people who are not making an effort, they will be left behind, and it will be just, they will be just as illiterate as in the old days when people could not read. If they don't understand computers, if they don't understand science, so it is a dual responsibility, both from the scientist to make things simpler and also from the public to make an effort to understand.

> **Nathaniel:** Well, I, again, if you - if you look at it from a humanitarian point of view, it's just improving the livelihood of people. I think, my

> understanding of how the world works is we have to keep improving so that we can live and survive. If you don't understand science well enough then it's going to be very detrimental to everybody in the long run
>
> **Fred:** But it, and it definitely is something that we talked about a lot last week because, and, and we're concerned, and more than a little bit concerned because, because our message doesn't get out and people don't know what we do, and people, in a lot of cases, don't uh don't appreciate science as much as they should, and it's a big problem.
>
> **David:** I think the end result should be, the lay public (pause) the lay public should know two things. One, they should feel comfortable with a lot of the technical jingo. So, you know, so if scientists talk about, I don't know, black holes, exoplanets, and the mathematicians talk about, say, calculus derivatives and slopes and lines, I think the public should feel comfortable with those terms.

If the public knew how important science was, the participants believed that there would be support, and hence funding for science. Some of the participants also believed that better public understanding of science would garner more interest in science careers. The pliability of the public and the need for the public to understand science and support it are also consistent with belief in the dissemination model of science communication.

> **Robert:** ... so that needs to be really explained to people, about how, how science affects society, how it affects the economy, how it affects jobs… I think more people would be interested in science and for those who are not, who don't go in that field, they will actually do more to support it regardless.
>
> **George:** I think scientific communication can serve two large purposes, one is to inform the general public about the importance or significance of result and how that might change eventually in your day to day lives ... But also to aid in the recruiting and piquing the interest of individuals who could become professional scientists.
>
> **Oliver:** Because they'll find it interesting, and then they'll support science when budgetary issues come up, so you want, you want somehow if you have a chance to communicate to your representative or senator or whomever, you want that enthusiasm, you want people to, you want there to be buzz about it because if people keep talking

> about it and write blogs on how cool it is that bacteria live on arsenic, that's going to mean that somebody somewhere is going to, the, it will help, sort of, increase the funding for science in general. So you want to get across A, what's true. B, why it's interesting and cool and hopefully people will, by virtue of their buzz, including presumably congressmen and senators who also watch CNN will say, 'Hey, that's cool. Let's increase the budget for whatever it is that supported that or science in general.'

What is the culture of the civic researchers?

Swidler's (1986) conceptual framework defines culture as a tool-box. A culture provides its members with the tools and mechanisms to help them deal with changes in their environment. In this research, the participants were asked various questions that allowed them to talk about the tools that they used to cope with changing science. They were asked about science in school and how their views of science changed over time. They were asked about their responsibilities and jobs, their views on the scientific method, and their views on science communication. They were asked for their views on social scientists and the social sciences. While all of these questions provided insight into the changing scientific culture, they also provided statements on how the scientists worked in today's research culture.

In this section of the dissertation, several aspects of scientific life will be examined: how the culture of science has changed, what the scientists believe their new duties are, the tools that scientists believe are helping them cope with this change, clashes between the traditions of science and how science communication is conducted, and what tools the scientists believe they still need in order to deal with the changing world of scientific research.

1. In the past, scientists needed only to get published, secure grants, and carry out basic science to find out how things worked in the natural world.

Several participants discussed the demands of science, especially when it came to research and funding. Tim discussed how young Ph.D. graduates were given a chance to prove themselves by being given funding. Fred and Oliver related stories of old professors in their department who occasionally "came up for air" but who were kept in the department because they were generating funds. Larry talked about being hired as a young professor because of his research capabilities, and at a time when teaching was not considered a priority. Irene also discussed how as a young graduate student, she did not need to "justify" her science or write about it for any forum other than a science journal.

Bethany also discussed the need for impact in one's work, versus the simple work that she had carried out in her early days as a molecular biologist.

> **Bethany:** In the old days we used to have a beautiful model system and just ask the questions about this particular animal works, okay? How the process of how stem cells become whatever and it was fascinating and beautiful work and NIH loved this work and NSF loved it and we would get funded. But the impact now, if we tried to put such a piece of work, submit it to NIH they will say, 'Oh, fascinating but the impact is nothing, basic discovery.'

Fred also talked about an increased need for interaction, as well as the need to communicate and work in teams.

> **Fred:** It's different now and so I think that's probably a change that's come about that you have to be, you have to interact with others more and better than what you used to have to ... And we all, you know, heard stories about, oh yeah, some old guy that used to be in there, turned out tons of publications and whatever and he couldn't get along with anyone in the department but that was okay because they got grant money and they, they did their thing. Nowadays it's harder, but there's still that aspect in some cases, but for the most

> part, I think it's harder … I think the communication and the management aspect is probably more important than it was.

2. Today, researchers need to communicate honestly in different ways to different audiences because they are the experts.

As mentioned earlier in this section of deductive analysis, the participants believed that they were tasked with communicating to different audiences because they were the experts. As David and Arthur put it, scientists were involved in science and were therefore in the best position to communicate. Ernest related how scientists were expected to give opinions to various media outfits if a science-related issue arose in the press.

Irene, however, did not like how science was more public.

> **Irene:** ... I think when I began working in science I, I didn't really expect to get paid a lot. I didn't really expect anybody to be writing articles about me or about my discoveries that weren't in scientific journals. I didn't perceive there would be such pressure from society to justify that my work was relevant to human health, improving the world. Not that I didn't think I had a, a reason to do good for society. I guess I didn't, I guess it was never a, a driving force in what I, what I've done ... So, what I've seen through the time I've been in science is going from having a really nice hypothesis-driven project which answers a specific question about a life science problem, one has to spend a lot more time thinking about how this relates to what other people are doing, diseases, you know, marketable products, whatever the case may be, which isn't, isn't something that I am very comfortable with.

3. The epistemological beliefs of scientists provide the tools for scientists to communicate well, but they still need the following additional tools in order to succeed: communication training, various intermediaries such as media experts in the communication process, and a general, more complete understanding of how science is learned and communicated.

Scientists were able to deal with the changes in science through tools provided by their own training as scientists. For some of the participants, the need to communicate was already native to the field of science, and researchers were already equipped with the idea that they were required to communicate.

Fred, for instance, talked about how graduate student training missed communication requirements in science, despite the fact that researchers were required to communicate in their line of work.

> **Fred:** Now, to actually do the job, and this is a problem that we have in graduate student training I think, is that when you, when someone trains to be a scientist they learn how to do research. When you go and are a scientist and to, to do the job effectively, I think the 3 most important things are writing, you have to be able to write effectively. You have to write papers, you have to write grant proposals, you have to write little white papers, you have to write emails and take messages and whatever to convince people to give you funding, to publish your papers, to get your message out there about this is what you've done, and that's something that isn't given much, much emphasis in graduate student programs ... You have to be able to speak. You have to get up, you have to get up in front of a group and tell them, this is what I've done, this is why it's good and all that sort of thing. Here's my research results [*sic*]. You have to be able to communicate with scientists, hopefully with others which most of us are not good at, but we can communicate with scientists for the most part, and you have to manage people when you're working in the lab.

While David understood why some scientists did not want to be involved in communicating science, he also believed that scientists were already social by nature.

> **David:** I do understand that there's a lot of scientists who don't want to get involved with various forms of media because they kind of feel that, you know really, their fulltime job is a working in science and not to have to worry about communicating these things, but ironically scientists communicate all the time, you know, in terms of writing papers, presenting at conferences, sitting down talking with their grad students, talking with their colleagues over lunch, so, I mean, science at its very nature, is a very social being. You know, even though mathematicians, you might consider them to be antisocial, we still collaborate together at colleges and universities and in fact, let's see, what is it, the Latin word of college, you know, is essentially the whole idea of, like, you know, a family, like a group of people.

Aside from the collaborative and interactive nature of research, the researchers also had several tools to aid them in their communication endeavors. These tools arose from the epistemological beliefs of science. First, the participants believed in the need for honest and truthful communication, which is already a norm in science, and which comes from the need to provide a basis for one's statements, as well as to meet one's obligations to serve society. Ernest, for instance, believed that the science that supports communication should be "sound." Kevin already discussed the issue earlier with "the good boy at the coffee shop" analogy when he advocated for scientific claims that were well rooted in good research findings. Tim also discussed the importance of truthful communication earlier, when he believed that poor communication would hurt not only the media, but the public as well.

The participants also believed that their expertise and credibility made them the best persons for communication, as already articulated earlier by David and Fred. This can be rooted in the value that scientists place on a good knowledge base, as well as their belief in science as a source of knowledge. Queenie provided her opinion on the subject when asked about what she felt was scientific data, and her statement can be traced as well to the epistemological belief that all claims must have a basis that is derived from good scientific methodology.

> **Queenie:** … we usually believe in what people say, but if there's some researcher saying that then I would believe in him because researcher or scientists, they don't, they don't talk about different things or they don't talk about the wrong things. If they are claiming something, then they are doing work to claim that because otherwise there's no point in claiming. So I would say I would look for the research or that paper or that article heading that and then I would believe it's scientific.

The participants also believed that their teaching experience has provided them the ability to simplify ideas, which also meant that they could communicate to the lay public. Christopher and Kevin believed that they needed to put things in simpler form to get past jargon of science and for people to understand science betters. Bethany and Oliver talked about how good teachers could also make good communicators, although Oliver also believed that the "lousy teachers" would be ill-suited for the task.

> **Bethany:** … I believe that most scientists like to talk about their work, and we know because we also are teachers. We teach in Biology, at the Veterinary School, we know how to take something complicated and make it simple ... So it's a pleasure for us to communicate. One cannot mandate it but I think when we're asked we should always say yes, we always offer, we say sure.

> **Oliver**: No, because there's some people who obviously are totally ill-equipped, ill equipped for that. I mean, we've all had lousy

> teachers and lousy teachers are probably going to be lousy people to do, no, there should be people who work at it, who feel comfortable doing it and who can boil it down to a few simple statements that don't boggle everybody's mind.

Even with these tools on hand, the participants still acknowledged that they required other tools to help them. Some participants thought that good training was needed for scientists who needed to communicate. Some of the participants needed intermediaries to stand between them and the public.

Fred agreed that communication and management training were required, especially since they were not stressed in graduate school. Arthur's statement agreed with his.

> **Arthur:** ... But also I'd emphasize that students really do need to take, you know, take courses in communications because almost all research now, out of necessity, has become multidisciplinary which automatically means you're working with, um with a diverse group of people from … different backgrounds, different skill sets, and students really need to be able to communicate and work effectively in teams.

Arthur, like Larry, believed that more studies were needed in order to understand how science was communicated and learned.

> **Arthur:** And how do we, and it's also, I will also say it's, it's an increasingly critical area. We have to do a better job of communicating science uh to the general population because we're failing miserably at that right now and I think especially in agriculture. I mean, we're just getting bombarded.

4. The epistemological beliefs and culture of science clash with the culture of science communication.

As the epistemological beliefs and culture of science provided the researchers with tools for science communication, so did they clash with the culture of science communication itself. Participants such as Fred, Irene, and Patrick pointed to the media in particular, especially in how the mass media misinterpreted scientists that they had already consulted with. Robert provided an example from his own experiences.

> **Robert:** ... I also, I had a couple of news stories that came out and so the, the news reporter would talk to me, and I would explain it to his person and then what they would have to do, they would have to try to change it for the general audience, so what they would do is say, okay, 'I sort of understand what you're saying. I'm going to go and type it up and I'll email it back to you and you let me know if I got it all right.' Okay? And then of course, I felt like going there and doing some editing because, even, even though I could see where they got that idea from, they're interpretation wasn't exactly, you know, the right one, so I'd have to reedit it, so all this editing going back and forth because if I edited something and I explained it in a different way, he was like, 'Well, my audience is not going to understand that.' You know, so I'd have to reedit it again in a different way, so, it, it stays correct....

Not only did the media misinterpret scientists, but the participants believed that it also misrepresented scientists. For instance, the media did not present an accurate picture of what scientists did compared with what engineers did. This portrayal was not only an inaccurate picture of science, but it also clashed with the epistemological belief that all claims had to have a basis in truth. Harold acknowledged that such a mix-up was occurring in the mass media and that the public was likewise making the mistake of believing that scientists and engineers were the same when in fact, scientists and engineers were "like cats and dogs."

Steven believed that the mixing of engineers and scientists in the media also kept children from having any interest in engineer, and thus not pursuing a career path in engineering.

> **Steven:** ... because I've seen lots of times where they say, 'Scientists say,' and if you actually look at the study they're citing, it's somebody from, like, an engineering, what I would consider an engineering kind

> of job, like they're in an engineering department at a university, they're working at a company and they have an engineering kind of background ... Because if you're a child, you know, reading the newspaper or you're a parent of a child, you, you think, oh you should be a scientific. And then when they go into engineering, you don't realize or you, you know, from a, well I guess something about more of, like, a career perspective, but you don't realize what engineering is.

As also mentioned in the previous section, the participants believed that the mass media portrayed scientists inaccurately, which led to a skewed perception of scientists in the lay public. George believed that engineers and scientists were portrayed differently in the mass media:

> **George:** ... And engineers are scientists but they have different goals. They're not trying to be first, because I think a lot of times the idea with Hollywood is that because some scientists are striving so hard to be first in something, they'll strive to be first in something that is, creates conflict with what the population wants ... Perhaps a scientist wants to be first in creating a, a biological organism that creates a lot of problems and the drive, whereas engineers, I think, often are portrayed as those who are building something or thinking of something bigger and better, stronger, faster

Fred believed that better media portrayal of scientist would change how the public viewed scientists.

> **Fred**: Scientists, we need to make our case and to tell people what we're doing and why and not let it, otherwise our public vision is Hollywood and TV shows and those kind of things which don't portray things too terribly accurately, so I've always said somebody needs to write a novel where the heroes are the cool scientists that go and solve the problems and save the world and everything and get, if we could get a popular novel out there about that, that would be a, that, that would help us out a lot (laughter) or have a TV show or something that, that was popular where the scientists were the good guys and not just the geeky weird strange ones that are trying to take over the world and cause problems, which they often have, you know?

Another clash mentioned in some of the interviews was how emotionally charged the media was. Such a clash can be traced to the value of objectivity in scientific research, as well as the epistemological belief that claims must be rooted in good methodology and research. Jessica already spoke of how the media fed on hysteria. Harold saw the focus on emotions as a problem with the mass media

> **Harold:** To, as they say, push buttoning, pushing their emotional buttons rather than, which is, which is really a, a severe problem in this country right now. We have huge issues that need intelligent discussion and good decision making but amidst all the emotional rancor it doesn't happen, so.

The media also twists facts or presents short statements that researchers find difficult to make. These clashes are rooted in the epistemological belief that repeated experimentation is needed to validate a claim, good research is needed to back up claims, and knowledge changes. Hence, scientists do not trust claims rooted in only one research project, or are backed by results from a small sample size, as exemplified by views from Fred and Irene.

> **Fred:** And, and you just, it's not, it's not realistic to, to do in some cases, a sample size is large enough to get really meaningful results. And so, if they don't tell you what they did or how many people were involved, then you just don't know one way or the other. But, I'm usually skeptical of a lot of what I hear on TV unless I, if I know enough about it to know, that's nonsense and a lot of times it is nonsense.

> **Irene:** It's this kind of push to go public with all this stuff that's, that is so, so, it's so misleading in, in many ways and you see that all the time, I mean, you know, this, this morning on the news there was, you know, you're not supposed to take vitamin D. You know, last week you're supposed to take vitamin D. Now you're, too much vitamin D is bad for you now. People are not, yeah, well no, I mean, you can take 500, 600 milligrams a day but no more because it can hurt your kidneys. What, why put that in, what, I'm just curious of why they have to put that out there. I don't know. Is it, is it really a proven fact? Is it just the result of one study that has come out? What, and why

> does it have to be publicized like, like that, because there are people, you know, like myself, my mother died of osteoporosis. I want to take a lot of vitamin D and calcium. These people are now saying, well, you don't need that much calcium and vitamin D. But, you, you see how confusing it is. So, I, you know, I am, I'm with the fact that I think that the, that the, this, this publicity surrounding science is not good. It's very dangerous.

Moreover, because science is too complex, ever changing, and has many implications, scientists find it difficult to convey their ideas in the small statements that the media want.

> **Harold:** ... when I have to interact with media, and I know it's going to be a 30-second sound bite, I'll spend a lot of time on that 30-second sound bite deciding what is the message that I really want to convey, and how can I do it in a way that they, they won't butcher it but it will get out there, it will be as honest a representation as I can make in a 30-second sound bite and say it in a way, and it's a tough thing to do. It's very hard. Much easier to write a scientific paper than a 30-second sound bite.

> **Oliver:** You have to be able to, if I'm being interviewed, as I was on national TV or radio or whatever, you have to be able to answer questions crisply and, and, but none of us get through what the basic ideas and why it's interesting, so, you know, I'm not the, I'm not the great genius in this, but at least I've spent time thinking about how to answer questions.

Scientists were also often pressured to publish only positive findings, which clashes with their epistemological beliefs of objectivity and the changing nature of knowledge. The researchers also cannot make a conclusion and simply suggest one, since they could only approximate nature. As a result, all findings, whether positive or negative, could be valuable to scientists. Arthur and Irene expounded on their ideas regarding the matter.

> **Arthur:** ... One of the other responsibilities um is sort of truthfulness in reporting the results, and I think to a great degree in um in scientific literature we have, you know, sort of created a bias of only publishing positive um statistical results, whereas in a lot of cases

> the, you know, that no statistical difference can be just as informative, but, but yet it's very, you know, it's very difficult to get studies published that don't show a significant difference. And so I think we have responsibilities of reporting results no matter what they are.

> **Irene:** I mean, I kind of indicated, it's much harder to get grant money these days, not because people aren't doing good science but I think because of all these expectations they have for your science. Very hard to get papers published these days because you submit something and it's, they always want more. They always want the big experiment. They always want, you know, some jazzy thing to be done. And, and that makes, that makes it difficult.

Participants were also often asked to provide conclusive statements to the mass media, but their findings could only suggest knowledge. Sometimes, the scientists simply did not know the answer. These clashes occurred due to the participants' epistemological belief in the tentativeness of scientific knowledge, and in science taking time to produce great discoveries. These clashes could also be rooted in the need to tell the truth. This made it difficult for the participants to communicate with a lay public that believed in absolute scientific facts. Harold, Patrick, Bethany, and Larry shared their experiences in communication.

> **Harold:** The most important duty is somebody has to tell it like it really is rather than the way people want it to be, so we need facts and we need careful interpretation of what really is and to tell, this is the hard part, and this is the part that people really don't understand is 2 things. One is that sometimes we just don't know.

> **Patrick:** And this is why when scientists are asked direct questions they often times don't give direct answers because, you know, it's really hard. I mean, science isn't, you know, they don't say global warming will warm the earth 4 degrees in 50 years. I mean, you can't, that, that answer isn't there ... So, you know, you just say, well, to the best of my knowledge, from what I've observed, we see that, you know, we project this and, and the margin of error is this, but if things change....

> **Bethany:** ... So, and the public wants to know if we have found an answer for cancer, for diabetes, for Alzheimer's, so but the advances

> towards, in science are, it is very rare that a very big advance will be made. It takes many years to solidify something and to move on to the next step. So, it is not always, we don't always have at the tip of our tongue the answer to a disease.

> **Larry:** Well, that's important too, and, and there you, you get into a very tricky issue because the general public, this is my, what I maintain, don't understand the notion of scientific uncertainty ... So, I'll make a general statement: the public doesn't understand statistics ... I mean, we're, we're not a very statistically, stati - we're not a very, we're not very knowledgeable about statistics and probabilities and uh, and such, and so that really inhibits rational discussion of many issues, so we see this all the time.

Nathaniel, who had studied climate change models, also felt a clash when he examined the climate change models that were shown in the mass media. His personal experience can be rooted in the epistemological belief that scientific knowledge can change, and scientists can only report the world to the extent of their own abilities and tools.

> **Nathaniel:** ... Because too often the lay public is given an idea about something maybe cast in stone when in reality there are tremendous assumptions that are involved with the conclusions that were drawn and people don't understand those assumptions. You know, unless you understand those assumptions, you really don't understand the significance prediction that's being made. That's why, a good example is, you know, bridges fall down sometimes because engineers pick up a canned code, and they apply it to design a bridge but they don't understand the assumptions that went into the model themselves and so they don't, they don't understand the end product, and so they might say let's take everything and multiple it by 2 so that it's not going to fall down, but if they understood the model well enough and the assumptions that went into the model in the beginning, then they wouldn't have to do that.

What boundaries do the scientists set between themselves and the lay public? Themselves and communicators? Themselves and social scientists?

Lam's (2010) boundary-setting framework was originally designed to describe the boundaries that participants perceive between themselves and industry. The framework is meant to characterize researchers based on how they perceive their roles to be in society, and how their work is affected by external forces. In this research, the original framework is altered to describe how participants might differ in their perceived boundaries between themselves and the lay public, mass media, and social scientists.

1. The researchers are Communicating Hybrids when dealing with the public: they are aware of their social obligations to communicate but experience no role identity tensions.

According to an adaptation of Lam's (2010) boundary setting framework, researchers can be categorized into one of the following four types on the basis of their perceptions about dealing with the lay public: Type 1 (Tight Boundaries) seek to protect science from feedback from or involvement of the public; Type 2 (Traditional Hybrids) test and maintain boundaries but feel role identity tension; Type 3 (Communicating Hybrids) negotiate and expand their boundaries but feel no role identity tension; and Type 4 (Communicating Scientists) link their work to communication and fit research following external demand and feedback.

Based on the data, a great majority of the participants can be classified as Communicating Hybrids. They are committed to the norms of science, and are also committed to communicating with and serving the needs of the lay public. They are secure in their identities as scientists even when they are tasked to take note of public interest and acceptance. Many of the participants acknowledged that they needed to help society. In fact, some participants had already been engaged in research projects that tackled issues such as sustainability and long term effects of their technology. For instance, Ernest was engaged in "complete systems analysis" projects for the College of Agriculture, where he and his colleagues studied long term impacts of their work. Kevin believed that scientists would always be needed because society needed the input of science even when the earth and societies changed.

Harold and Arthur took it as their duty to improve the world through their research. Even Arthur was willing to change research focus if it meant that he would produce more "meaningful" work. Despite this willingness to change, the participants did not exhibit role identity tension, which is consistent with their identity as Communicating Hybrids.

> **Harold:** ... maybe I have a prejudice that I like to think of scientists as the good guys, that we, you know, we've done marvelous things in terms of combating disease and in terms of providing technologies that make life better. There are, there are, so we, so we have a duty to do that, to, to try to make the world a better place. We also have a duty to clean up after ourselves.

> **Arthur:** ... and then the other thing that I think is – is important is um how do I contribute to research teams here on campus? So even though I may be interested in doing a particular project, if I can contribute to a different project for the good of a team that's got a bigger goal and can accomplish more, um then a lot of times I will, I will do that. I'll shift my focus.

The participants also believed that because taxpayers were paying for their work, the public expected them to communicate in return. Bethany believed that communicating was her way of giving back to taxpayers. Patrick's, Harold's, and Fred's views all agreed with hers.

> **Patrick:** I mean, there is sort of an overarching thing is that people do expect scientists to be a source of knowledge and, and when they ask a question they don't want to come back some, some time later and find out that you asked, answered the question in a way that was politically expedient ... They want, they want really, really sound information.

> **Harold:** ... They want something in return, and they deserve something in return. One of the reasons why I give public talks ... is I owe these people, and they're paying for my job, my research, you know, they're, they're taxpayers, and I should, I have a duty to try to explain to them what I'm doing, why I'm doing it and hopefully when I finish I'd like them to think that it's money well spent.

> **Fred:** ... one of the things we all concluded was that we need to convince, because we're funded by the government, by the taxpayers, but the taxpayers don't know who we are or what we do or why we're doing it and what they're getting for their money, and so that's one of the things that came out of the meeting on the economy was that we need, we need people to be advocates for us and we need to be advocates ourselves, but to get our message out there, and how do we do that….

Not all the participants, however, believed that they owed society anything. For instance, even as he believed that scientists needed to communicate with the lay public, David did not believe that science existed for the greater good. As mentioned earlier, Irene did not believe that she needed to justify her science.

> **Irene:** I think in the, the mid part of the last century, I think the public in general was very supportive of educated people doing research in interesting areas regardless of what they were, but whether it's been the politicians or whatever the case may be, making it more that, you know, you have to justify what you do for the, you know, for the goodness of man or whatever is, I don't know. I don't know ... I mean, I'm a big, I'm a big proponent of academic freedom when it comes to scientific research and as I said, I, I find it disturbing that, that society as a whole is, is constantly putting these pressures on us to justify kind of what we do ... And, and you know, I, I understand the reason for that. I mean, it's government money

> that's being spent on science and, and you do have a responsibility to articulate how you've spent that, that money and to assure people that you're doing good science that is, that is reaching a particular goal that you have in mind ... The, the problem that I have is that, you know, again, there is this constant push to make it more than what it really is...

To Larry, however, communication was not about justifying one's science, but sharing one's love for the field.

> **Larry:** … that's the wrong issue though. It's not a matter of justifying. It's a matter of do you want to share it, your enthusiasm? Maybe you don't.

Larry went on to share his beliefs about how physicists liked communicating with the public, which showed how he was a Communicating Hybrid.

> **Larry:** I think most physicists, this is speculation, let me, hear that (directly to the recorder, followed by laughter)? Welcome the opportunity … to share their enthusiasm with a, an audience of non-experts.

2. The researchers believed in keeping tight boundaries when working with the media.

The participants, in general, did not like working with the media. They believed that the media could engender support for science, but they also believed that the media needed to portray scientists accurately. They found it difficult to work with the media because according to the participants, even the media who had consulted with scientists would still misrepresent them. It was for this reason that scientists generally avoided working with the media.

> **Patrick:** Yeah, or intentionally, intentionally, you know, twist things around to sort of make you look bad for some reason, just, I guess, just to splash up the, the, whatever they're doing. It's only happened once or twice, but it was awful, and you know, has a tendency to make you not want to work ever, well, not work with that particular person again.

> **Harold:** ... as I said, sometimes a science writer will take it and, you know, God help us with what they do with it. And I've worked with a lot of science writers, and there are good ones and I have a lot of respect for and there are ones that are just awful ... So it was one of those things where, you know, you got to, you got to have a little bit of a thick skin to get interviewed by science writers and put and, and media and stuff because invariably they're going to get what you said wrong.

> **Irene:** And it's the responsibility of those reporting that to accurately write down what you have said. That does not happen, as many of us know who have ever had a quote in a newspaper. The way that it's stuck in there, you say, 'Oh my gosh. I, you know, I didn't say that. I mean, I didn't mean that.' And, or it just sounds so out of place and I, I, I think both sides have a, have an important responsibility here. I mean, everybody wants to interview the scientist. The scientist has to be very careful about what they say, because it can be misconstrued by that person, twisted around and made to sound more important than it is.

While Irene believed that training would help researchers work better with the media, she also revealed that she believed that most scientists did not like being interviewed because they risked being misinterpreted. Like many of the other participants, she did not like the mass media. Most of the participants, however, believed that they needed to communicate on their own without having to deal with the mass media.

Some of the participants also believed that they welcomed the chance to work with intermediaries, where the researchers would still provide the knowledge that the media needed, and would correct media work. These participants fell more under the Communicating Hybrid typology because they still were open to media work. Patrick, for instance, believed that researchers did not always need to be in the limelight even if they were needed to communicate directly.

> **Patrick:** ... Well, you got to have them in there somewhere because otherwise you get people who get carried away or don't really know

> where to stop or really don't understand the depth of it, so they've got to be involved in it somewhere along the line. Are they in front of the camera all the time? No, that's probably a bad idea.

Tim, Christopher, and Nathaniel believed that intermediaries and message-checking by scientists was the best way to communicate science. Their involvement with the mass media in this case is consistent with the Communicating Hybrid type of relationship.

> **Tim:** Because basically, I do not think they should write the communication, but they should see the communication and make sure that they don't have any kind of flaws in them, and science should be reported truthfully and meaningfully – and second when people read, they believe it ... But also I think scientists can definitely read and definitely o make sure that no fallacies or other misunderstandings or by language or the translation, actually.

> **Christopher:** Now as far as going from that raw product to the bullet points that I mentioned, you know, the, the, the stuff that people can easily digest and understand and learn something from, I think that the scientist should probably be involved at the end, look at what is the product or the boiled down version of what they originally started with and say, 'Yeah, okay, I think you have it right,' or 'That's pretty close.'

> **Nathaniel:** … But, no, so I don't think every individual needs to be able to do that, communicate effectively their science – you know, as long as you have an intermediate, somebody that's in the middle between you and the real world, I think that's more than sufficient.

3. It was difficult to discern the boundaries that researchers set between themselves and social scientists because they did not express any need to work with them

None of the participants in the study spoke about experiences working with social scientists, or whether they wanted to work with social scientists. The participants nevertheless provided their views on the social sciences.

For instance, Robert believed that any field could be science as long as it studied and tried to make sense of things. Kevin echoed his views, and added that exploring any kind of entity using experimental design and "proper data analysis" were essential to being considered a science. Some participants such as Larry, Michael, Patrick, and Bethany assumed that social scientists practiced objectivity, carried out experiments, had governing laws, and used numbers, and were therefore part of the scientific community. In this sense, Larry, Michael, Patrick, and Bethany seemed to be opening the boundaries of what constituted science to fields that practiced the methods of the bench sciences, and without feeling any role identity tension.

> **Larry:** Well, I mean, look at, turn it around. If they weren't, if social science weren't a science, then would we have learned anything after all the years of social scientists working? I think we've learned a great deal, so, I mean, that's evidence that somebody's doing science.
>
> **Michael:** Absolutely. I mean, that's why it's called social sciences. Otherwise it would be called social. No science. So, yes indeed. It's just the different laws are perhaps are governed, or maybe the same laws but I just don't know, you know, so ... I, I assume, I mean, I haven't worked in that area so I, I see them. They, they, I mean, we have Newton's Law ... In, in, in engineering, and we use it all the time. I'm assuming that perhaps there is a law or is some science base that it is in social sciences and that they use, you know, so, yeah.
>
> **Patrick:** ... because if what you define as science is, you know, limited to certain disciplines of science, then yeah. I mean, we have a very narrow view of it, but if, if your concept of science is, is sort of how I was defining the job descriptions just sort of investigation driven, then certainly there are all kinds of sciences out there ... And so, yeah, no, I have no trouble seeing social scientists as scientists, because they do just that, they, they, they run experiments, and they have hypothesis, and they gather data and that's it, just like any other scientist. Their subject and their subject matter is just different. It's all the same.

> **Bethany:** ... but if they set up an experiment in a way that the conclusions are based on controls and the numbers - and statistical analysis and the numbers are large enough to support the conclusion, then that's science.

Steven believed that the social sciences could be considered sciences if they used the approaches and results of the bench sciences.

> **Steven:** Well, I think that if you, if you should have some sort of a mathematical or scientific approach to what you're doing ... Anybody who's doing anything that, like, relates to scientific results and say, I think of psychology like medicine, you know, like sociology that's using things that relate to, for example, statistics … or, I guess it has to, I guess my sort of definition has always been, it has to somehow touch, you know, like the natural sciences.

Queenie also believed that the social sciences were sciences because they could teach society how to improve itself, but they were not necessarily using the tools of the bench sciences.

> **Queenie:** ... So some people say they are not doing anything valid because it is not like math, so in math you have certainties. If something happens and, you have to prove it. When you prove it, it is certain. But for social science it changes because it is about either human behavior or social setting, and it changes from setting to setting, it changes from person to person. It has lots of variables and I, I hate when people say social sciences are not the usual science, because it has not been done in the laboratory, but I, I'm, I'm opposed to that. I, I think that they are more, they are as valuable as the natural sciences like math or the chemistry because they're, we have to know about human behavior, and we have to know about social interactions with people or social sciences so that we can improve ourselves as a society.

Some participants believed that the social sciences did what they could with the data that they had. Fred, for instance, knew that there was a limit to using experiments, especially where humans were involved.

> **Fred:** ... You can design some experiments to test under some things, but predicting only certain individual, you can come up with probabilities maybe, but I think it's not going to be as easy whereas if

> I have a cloned genotype of a plant, then I can predict, oh, this one does it this way and if I do it again in 10 days it's going to do exactly the same. Well, a human may not ... And so, I think that's the difference. But in terms of doing the method, I think they, I think some scientists do the best they can with what they're about to do ethically and sometimes maybe they go beyond that, but most of the time I think they don't, I mean, it's the same, it's the same thing.

Fred believed that the data generated by the "softer sciences" did not provide as much information, and that numbers were needed in order to analyze research. He also speculated on how interview data could be scored and analyzed using numbers.

> **George:** Everything else is weaker. But, I think, you know, even in, you know, the 'softer sciences' of sociology and psychology where you, it's still a very rigorous process where you have these sets of ordinal data or descriptive data but it's, it's a, but from what I've been reading in psychometric kind of things, it's still a completely rigorous approach and you have a lot of the same issues as you have in other fields so, for instance, I imagine the outcomes of this interview will be scored via a well-defined rubric that's been debated among you and your colleagues to perhaps organize the outcomes of these questions into ordered pairs or related pairs into classifications ... There has to be a way to have bona fide measurable differences, but that could be quantitative, it could be semi-quantitative or it could be more qualitative or ordinal type of data.

Ernest's view on the use of statistics and numbers agrees with George's assessment of how interviews needed to be analyzed.

> **Ernest:** ... but it, it takes a hard science, it takes some, okay, how are we going to test those who are really different in setting up interviews or setting up something that you can apply some statistics to that that is different than that ... You've got to put some numbers to your observations at some point.

Harold defined the work of social scientists as "squishy" and believed that they needed to collect the facts and interpret them objectively. He attributed this to the "fuzzy" data that social scientists dealt with. His statement on how physical scientists do not like dealing with social science data may also point to the tight boundaries that bench scientists sometimes set between themselves and social scientists.

> **Harold:** In social science, there's a lot of things reading into what people's motivations are, what people's, it's, it's, it's harder, okay? And as a result, and I respect that, that it's harder. My one thing that I would like to see social scientists do, though, is realize that their facts are squishy, and therefore they should be very careful when they, when they try to come back and reach results from those. They should not over interpret ... I see a lot of very simple things done that, I mean, you stand back and you say, 'You could get any answer you want out of that'... it's not fuzzy because the social scientists are fuzzy. It's inherently fuzzy, and in fact, many physical scientists are uncomfortable dealing with that. They can't cope with it. They don't, they feel extremely uncomfortable even dealing with it, and I think that says something. So I think we have to cut the social scientists some slack and basically say, 'You've got a tougher job than we do.'

Tim agreed with Harold's statement on how social scientists needed to avoid overinterpreting their data. He also believed that social scientists needed to be taught the "proper way of analyzing data."

Nathaniel, on the other hand, kept tight boundaries between his field and the social sciences. When asked about his views on social scientists, he called the phrase "a contradiction in terms" and went on to explain that he was not convinced that social scientists were doing science.

> **Nathaniel:** I guess you'd say, what you were talking about before, scientific method and things like that. The social scientists, what they do is often, foremost subjective ... Than what the physical scientists and the mathematicians, and so I always took it with a grain of salt (pause). They, they work with what they have to work with.

Discussion of results from inductive analysis.

This section of the dissertation addresses the final research question: What other aspects of research, though not covered by the conceptual frameworks, can be valuable for future research? In order to answer this question, the researcher conducted an inductive analysis of the data. Inductive analysis involved rereading the interview transcripts for data that had not been coded or did not fall into the conceptual and theoretical frameworks used in deductive analysis. As the researcher read through these parts of the interview transcripts, she searched for frames of analysis: these were data that appeared significant, were repeated through the rest of the interviews, or presented intriguing avenues for future research. The researcher found that the participants' critique of the social sciences, their discourse on their families, as well as their reactions to the interview were repeated through most of the interviews and were also interesting.

The researcher then searched for semantic relationships among these frames of analysis. This search yielded the following domains: characteristics of the social sciences, family influence on career, teacher influence on career, and positive reaction to interview. These domains were used to recode the interview data, and both confirming and disconfirming data were marked as part of the domain. Each domain was analyzed, and themes were searched for between and among the domains. There were no themes that were common to all the domains, but each domain was dominated by a major theme. These major themes are presented as generalizations in this subsection, and are substantiated by quotes from the data and a discussion of these quotes within their respective contexts.

What other aspects of research, though not covered by the conceptual frameworks, can be valuable for future research?

School initiates interest in science.

As mentioned earlier, some of the participants believed that school science was very different from how it was truly practiced. As a result, some of the participants criticized the educational system. For instance, Harold believed that it removed any interest that students had in science.

> **Harold:** Well, I, I can't be and I still, like I said, I love science. I love doing it, I love, I love teaching it and I especially love, you know, getting, I, I get students at the other end of the educational pipeline after they've had a lot of their interest in science beaten out of them by the educational system, which I'm not fond of, by the way ... I literally, I'm, what I call myself is a self-educated Ph.D. and I literally was, I learned most of what I learned long before I ever got into school, and so it was just having to jump the hurdles and get the, the letters after my name, but it was not a useful process for me, and it isn't for a lot of people ... It's for some mythical average person, and I'm not sure who it's good for, but, it certainly wasn't good for me and I see, it's not good for a lot of people so I have to reignite the spark in a lot of people that have lost their spark because they've had it beaten out of them. They couldn't beat it out of me, so.

To Jessica, who was currently reviewing students' applications for veterinary school, school science did not prepare students for research work. She believed that there was no stress on the importance of education, and students in the U.S. were at a disadvantage.

> **Jessica:** Well, I think for, if you look back at high school, college and what, at whatever level it is, it's unfortunate because here in the United States I believe that it's probably not so, we learn by factoid information, and science in the classroom is a lot of factoid information, and unfortunately I don't think we are taught to think. It is difficult for the students, in particular, when they come to veterinary school because we challenge them to think.

Despite the fact that the participants criticized science in schools, they also acknowledged that their interest in science had been prompted by school. For instance, Patrick was encouraged to pursue scientific research because he was good at science. Nathaniel was motivated by his 7th grade science teacher, who he even recalled by name.

> **Nathaniel:** I guess if you want to go far back it was my 7th grade science teacher ... We had projects like trying to figure out how far the moon was from the earth, how old the Grand Canyon was, some thermodynamic problems, and these were for, I don't know, students who had really no science background at all because you're in 7th grade, and he was just an incredibly motivational, and ever since then I've been interested in science. I've always been good at mathematics, so, the rest of it comes pretty easily.

Bethany not only did well in science, but was struck by a question that her teacher had posed.

> **Bethany:** ... but I remember one day uh my biology professor, I was maybe 16 years old, just asked this very simple question about are you, does anybody have any questions about life or how, you know, things come about and - I remembered how it struck me as a young um woman, and the professor was a female as well which was very unusual in those days, um for Greece to have female teachers, especially in science. Um - But that's what I remember. And I was a good student. I did well in math and in science.

Like Bethany, Christopher's professor sparked his interest in entomology and consequently, what would become his graduate career:

> **Christopher:** ... As I went through college I had an entomology professor who really opened my eyes to a lot of things, you know, of biological and insects are such interesting animals. I mean, they really drive a lot of things that we don't understand, that you don't, you don't necessarily have an appreciation for until you look closely and say, well, why are the trees doing the things that they're doing? A lot of times the answer is because of insects, you know, have forced them to adapt to do the things that they do, so I really became interested in entomology at that point and I went on to graduate school.

Like Bethany and Christopher, it was the influence of a college professor that made Irene pursue a career in the sciences. The university environment also prompted Arthur to pursue his current research after he found all the research options that he could go into.

Actually doing hands on work initiates and sustains scientific research.

The participants' interest in science also seemed to stem from hands on work, whether in their childhood or through the work of a mentor. This hands-on work also sustained their interest in science. For instance, Arthur and Bethany both grew up on farms, and Ernest was exposed to 4-H work at an early age. David grew up next to an airport, and began asking questions because of the airplanes that he saw flying overhead.

> **David:** Just really having an interest in how things around me work, you know? I was just curious in how everything worked. I grew up not too far away from Los Angeles International Airport which meant that every day I saw airplanes flying over, so, you know, I just always wondered what kept the planes aloft, you know, how did things works and I guess really from that, I mean literally, just seeing airplanes flying over every day.

The society that Harold grew up in encouraged scientific research:

> **Harold:** I call myself a Sputnik kid. In the late 1950s Russia, of course, launched Sputnik. There became a panic in the U.S. to develop new scientists, so first of all I was very interested by science and particularly the space program, and secondarily I had marvelous opportunities ... They, they, they, you know, gave me all kinds of opportunities so I started taking college courses when I was 12 and 13, summers and weekends and things like that, they made special programs for me, and then as a result of that, it was, I had, you know, about 2-1/2 years worth of college credits before I graduated from high school.

Family involvement in the sciences was not enough. Oliver's family was interested in how things worked, Christopher went hunting with his father, and Michael and his father worked on cars together. Fred's father was a researcher, and he and his father shared a love for the outdoors.

> **Fred:** And so I was always around science and doing scientific things, and from a very early age I was always interested in the outdoors and biology and things like that ... and then my father would take me out on geology field trips hoping to interest me in geology but I was never too interested in the rocks and the dead parts. I was always much more interested in the living parts and got interested in plants, so that that way I could be wandering around in the woods a lot, and then it might have been when I was about 10 or 12 years old my father went to a conference in Palm Springs, California, and when he came back he brought me a thing of cactus plants that he had bought somewhere and growing up in Virginia, you know, they don't really have cacti too much and I thought they were just very cool, so I grew these cacti and read all these books about it and always wanted to go out to the deserts to see cactus plants and that sort of thing....

The participants also worked on science-related activities as they were growing up. Larry had a telescope and math puzzles to work on. David worked on electronics early on, and Robert played with toys that he had made on his own.

> **David:** Yeah, like I actually learned how to create my own batteries, spent a little bit of time dabbling in, like, computer programming, so, you know, even when I was in the 4th grade I guess it was, I would actually come back home from school and I would just sit there and try to program on the computer.

> **Robert:** ... so I would not have lots of toys, and then when I did have a toy I would get quickly bored with it, and so I always wanted a new toy, but we, of course, we couldn't afford new toy all the time. So what I would do was take paper and tape and create structures and make my own toys, and all these weird, you know, shapes and things like that, and then, so my mother kept seeing me do this, and she asked me, you know, what I wanted to be when I grew up and I said, you know, 'Well, I want to be an inventor.' (laughter) And she said, well those, she, she, she said, 'Those are called engineers.' (laughter) So, that's my first, the first time I heard it about that term.

Having a mentor that encouraged hands on work was also important to sustaining the participants' research. For instance, Arthur was “turned loose” in a professor's laboratory and encouraged to do research when he was an undergraduate. Christopher was exposed to various experimental approaches through the work of his mentor. Irene was exposed to various laboratories that enriched her own research work. Queenie's mentor introduced her to new approaches to math problems.

> **Irene:** I, I think it’s, of course it’s very important, I mean, the, the, the whole idea behind research science is, it is kind of like an apprenticeship in that you work in someone’s laboratory, and you learn how to do science, and you learn how to do it correctly. You learn how to think about problems. You learn how to troubleshoot problems. You, you need to have direction in that. No one is born with those skills. One has to have the supportive environment in which to learn those skills.

Like Irene, David saw mentoring as a way to train scientific thinking in students.

> **David:** Because, because you know, if you’re a scientist, that’s the way that, that you’ll think about it, you know, come up with the right question then we’ll come back and talk. Whereas, of course, the student is not a scientist, and he doesn’t realize that. So a student of mine will sit there and kind of ramble about things, throw out different ideas to get a rough idea of what’s happening, and then eventually you can train that student to be a scientist by saying, ‘Well, you know, that’s a good idea for that kind of class, but, you know, have you thought about this?’ And eventually say, ‘Well, had you thought about asking yourself what kind of major you want to have, what kind of things you want to do with your career, what kind of career you want to have? So I’m saying, like, you know, they eventually train that person to ask the right questions, that is, to train the person to be a better scientist.

George's mentor argued with him and clarified his own thinking.

> **George:** Another advisor I had, we would talk for hours and argue and we’d, not, we wouldn’t argue like, personally, we’d argue about

> the science, and we were very, I'm a very confrontational person, he's very confrontational, and so we would get into these very confrontational heated debates that involved many, many, many, many pieces of chalk on the chalkboard, and we would just go at it. A whole afternoon would go by and, but we'd both have, you know, our thoughts combined and, and defended and changed and modified, and that was very, very cool.

Michael and Nathaniel believed that mentors could guide their students through the real world of science, which involved administration, politics, and industry. Steven's, Fred's, and Ernest's mentors taught them how to communicate in science by preparing them for conference presentations. Tim's mentor also trained him to write papers, and allowed him to work on a paper in order to see how he would contribute to science:

> **Tim:** Oh yes, I had a mentor in Ph.D., which really made my life very-very important actually. Because uh - After working four or five years then I wrote my first paper, he said okay, go and do it again. Unfortunately, I used to smoke actually, so I used to go back, smoke a pack of cigarettes all night, gave a new draft to him – and he would say, go and work on that thing. For three or four years-for three or four months—we kept doing that, and ultimately I begged, 'Please tell me what is wrong with it!' But he wouldn't tell me after a couple of months. It took a couple of months and he said, 'Think about that. Are you repeating people's work or are you doing something original?' Think in original terms what have you done, is anything worth reporting there?

Despite these advantages of mentoring, Bethany disagreed with strict mentoring and believed that it could be an "overpowering relationship."

> **Bethany:** ... now today, you know, we always start with mentors, um which is wonderful but on the other hand, it is as if we don't allow the person to emerge and develop what he or she needs ... But on the other hand, especially with the people who are very driven and uh they have their own uh thinking, a mentor can be an overpowering relationship. So one has to be very careful of what we, especially these days, of what we consider as mentor. One, it is the same thing raising our children. One has to be fair but not overpowering.

The need for hands-on learning has been explored in the science education literature, and its influence on participants' initiation into science has already been explored (for instance, Jones et al., 2010 and Zeldin & Pajares, 2000). According to the participants, however, an encounter with a single person was not enough to spark their interest: they needed to do hands on work as well, or they needed to actually be introduced to scientific approaches and laboratory work. They did not always mention family members or even economic reasons for going into science, but their sustained interest in science was largely due to actually working in the field.

The researchers appreciated the interview process and intention.

Many of the participants said that they wanted to do the interview because it involved talking about science communication, which they believed needed to be improved. Some of the participants, such as Christopher, found it “interesting” and even “fun” because they had never been asked the questions. Oliver thought that the review was “refreshing” because it allowed him to step outside his own scientific work and examine his philosophies.

> **Oliver:** It was a very interesting interview. I mean, it gives me a chance to, you know, step back from the day-to-day grind, if you wish, of doing things to see why we do what we do and what, what we like about it and so on. It’s, it’s refreshing to have a conversation like this, especially as you yourself are a scientist, so you can understand what I’m talking about.

Bethany liked being interviewed and likened the process to therapy.

> **Bethany:** Yes, and actually I haven’t had the, nobody asked me before all of these questions or nobody has really asked me of what, what is the responsibility of science to society. Those are beautiful questions and I thought that you did a very nice job in selecting the

> questions and it was sort of, um you know, it's like talking to a therapist. (laughter)

Both Arthur and Christopher believed that the interview challenged them to think. Arthur went on to explain why.

> **Arthur:** ... Really just because many of the questions were things that I really don't think about on a day to day basis, so if - if I'm a scientist it's almost second nature to come to work and follow the scientific method and do science without really thinking that much about how to describe, um, how to describe the, the overall, the big picture, the, um the field that we're in, because we get so focused, I think, on, you know, the, what are the results that we're working on or the project we're working on right now versus what's the big picture, and how do we define who we are?

Robert thought the interview was important, and that it revealed to him how he had an opinion on different issues that he had not yet thought of. Larry even asked to be invited to the researcher's defense, and encouraged the researcher to publish research in a bench sciences journal in order to call the attention of bench scientists to the issue of science communication.

Combined Frameworks for U.S.-Based Participants

This subsection of the Discussion section will discuss the findings from the U.S. phase of the study. Each subsection will present a summary of the findings, followed by a discussion: the first subsection will discuss findings in a combined framework of worldviews, culture, and communication models; and the second subsection will discuss findings in a combined framework of culture-as-toolbox and boundary setting.

A combined framework of worldviews, culture, and communication models.

A deductive analysis of the interviews and field notes from the U.S. phase suggested that the participants valued advancing knowledge and the scientific field, objectivity, ethics, having an impact on society, rigor and good experimental design, integrity and honesty, and passion for learning. These values, as well as the participants' epistemological beliefs, gave rise to their perceived norms, which included open-mindedness, critical thinking, admitting one's mistakes, careful and systematic work, asking questions and exploring, learning and establishing a firm knowledge base, truthful communication, working on high-impact research, disagreements amongst scientists, and mentoring. The participants disapproved of data manipulation, losing creativity and critical thinking, plagiarism, and sacrificing integrity for money. These behaviors, the participants believed, would destroy a researcher's career and reputation. The participants, on the whole, saw their work in science as a hobby, and not a job. They recognized that they had common traits that might make it difficult for them to communicate or even relate with the lay public. They had been socialized through years of school and training, but they also recognized that the science that they had learned in school was different from how it was truly practiced.

The researchers also work in a culture that constrained what they believed to be good research behavior. Funding pressures were taking away the integrity of science and the researchers' freedom to do basic science or pure inquiry. Politicians abused the facts and knew nothing about science. The mass media misinterpreted the researchers' work and misrepresented them as scientists, which made the participants skeptical about working with the media. The participants also believed that the lay public was confused, ignorant about science, and anti-intellectual. They believed that religion could inspire some questions or direct them toward some research problems, but they did not believe that it should affect how individual scientists worked. Some participants also believed that the American culture emphasized creativity and recovering from failure, which they believed were traits that were valued in research, and which they sometimes did not find in other cultures.

With a few exceptions, the participants practiced and espoused a post-positivist worldview.

As already mentioned in the previous section, the science education and science communication literature have already dealt with the perceived norms and values of science (Berk et al., 2000; Hermanowicz, 2006). The old Mertonian (1942) norms of communalism, universalism, disinterestedness, and organized skepticism are not always agreed with, and the norms can change depending on the research atmosphere in which the participants find themselves. In this phase of the study, however, the four Mertonian norms are still manifest, albeit under different definitions. For instance, publishing and sharing knowledge, a norm mentioned by the participants, is related closely to the Mertonian norm of communalism, where knowledge is shared in common amongst researchers. The participants, however, acknowledged that it was difficult to practice when they were being pressured to publish only positive results. The norm of universalism was also articulated to some extent by some of the participants, who believed that scientific practices and principles were the same all over the world. This norm was not followed by all of the participants, as some of them recognized the cultural differences among the scientists that they had worked or interacted with. The norm of disinterestedness was also manifest in the participants' stress on objectivity and open-mindedness, as they operated under the epistemological belief that knowledge was changing and they therefore needed to lose any investment in their research problems. Finally, the norm of organized skepticism was found in the stress that participants placed on critical thinking. Because knowledge was always changing, the participants knew that they needed to keep an open mind as well as look at all findings with skepticism, or they would “see what they wanted to see.” In handling their work with skepticism, the participants also added that they needed to let other people conduct the same tests on the same data to confirm their findings. These views are reminiscent of the post-positivist worldview, which stresses objectivity in the form of the work of a collective, rather than the individual scientist.

The differences between science in the real world and science in the classroom have also been dealt with in the science education literature, and there is consistency between the views of the participants in this study and participants in other studies (Harwood et al., 2002; Monhardt et al., 1999; Schwartz & Lederman, 2008; Wong & Hodson, 2009; Zeldin & Pajares, 2000). To the participants in this phase of the study, school science was a boring black box, where no further research was needed, scientists agreed on all their findings, and scientists simply needed to stay in their laboratories and work. As the participants in this phase of the study disclosed, however, this was far removed from science and engineering in practice. While many of the fundamentals were the same, the participants also began to find out that many of the facts that they had learned were changing and would still be subject to change. This gradual progression of learning about the real world of science can also be attributed to a change in epistemological beliefs: in the classroom, knowledge no longer changes and science can exist as an objective bubble outside of society; in the real world, knowledge is far less certain, and science needs to work with society. The shift from positivist to post-positivist thinking occurs as the researchers are socialized into the field of science, and as they are taught to embrace the epistemological beliefs that fuel their values and norms in the field.

For those who do not go further in science, however, knowledge remains absolute, scientists have all the answers, and all scientists need to agree on their findings. This positivist philosophy was alluded to by some participants, who talked about the “mechanic's appreciation” or “layman's appreciation” of science. This layman's appreciation might make it understandable for the lay public to trust scientists less when they see scientists argue and disagree over science-related issues, or when they see research findings presented in the mass media, only to be retracted or debunked some time later.

It thus becomes understandable as well why some of the participants are completely positivist or post-positivist. Ernest and Oliver have had to deal with funding agencies or the mass media, where objectivity is not held in high regard, and where scientists sacrifice their integrity (and hence, give up their epistemological beliefs, values, and norms) if only to receive funding. Ernest and Oliver need to maintain a positivist worldview to protect their interests and practice as scientists. The rest of the participants are more open to the changes in funding and mass media, and recognize their limits as scientists because of their socialization into the field. Nevertheless, they embrace their epistemological beliefs and hold on to their identities as scientists.

The participants might feel that their values clash with those of non-scientists, politicians, the mass media, or even religion, but they are also able to delineate their lives such that they are not influenced by the surrounding culture. The key to the success of this delineation might be found in how the participants regard their work. They see it as a hobby, as something that they are passionate about and interested in. In the words of some of the participants, they are simply "playing" and "having fun" while getting paid. While the participants might be flippant about their approach to science, their overall worldviews and science culture are very much interlinked. They have a much stronger culture of science, one which suffuses through their daily lives, and one which they practice in a culture that actually encourages their creativity. While funding might be a problem, and while the lay public might be anti-intellectual, the participants are still working in a cultural milieu that provides outlets for creativity and encouragement to rise from failure. Research work, therefore, despite the constraints, is not curtailed.

As in the previous phase of this study, the U.S.-based participants also expressed their problems regarding funding, a problem that is common in much of the literature (Lam, 2010; Varma, 2000). Also, as mentioned earlier, funding constraints can encourage cutthroat competition, interference with peer-review processes, and careless research conduct, among others (Anderson et al., 2007). These strategies for getting funding were mentioned in the participants' interviews, and the participants likewise expressed their frustration with the funding situation. Their frustrations were rooted in their epistemological beliefs, values, and norms as scientists, which appeared to be under attack when industry and politics came into play. However, some of the participants believed that science needed regulation, and funding needed focus in order for research to move forward. Such a belief can be rooted in the participants' post-positivist worldview, where they fully recognize the interdependence of society and science. The participants also believed that their fellow researchers could never be completely objective, and outward forces were necessary to control scientists. Even Irene, who wished for “scientists to be left to their own devices”, understood that researchers needed funding and needed to help society. Whether they accepted it begrudgingly or wholeheartedly, the participants' post-positivist natures always came into play.

There is only a single worldview that the scientists espouse, but they also have a dual view of a science *that appears to be* and a science that *is.* The participants in this study recognize that the science *that appears to be* is the absolute science found in school, as well as the maniacal science found in the mass media, both of which the public believe in. The participants in this phase of the study also recognize, however, that they live in a science that *is*: researchers do not agree with each other; researchers cannot offer any claims with finality because they are limited by current technology and their own biases; and the researchers can only provide the best information that they have at that point to make as truthful a claim as possible. The participants believe that the science *that appears to be* clashes with their worldviews and culture as scientists, and is doing damage in the lay public. Therefore, the participants want to communicate not only what the facts are, and not only for the public to understand the facts, but for the public to be comfortable in and deeply know the science that *is.*

In order to understand how the participants' worldviews and culture influence their science communication beliefs, the frameworks of worldviews by Guba and Lincoln (1994) and science communication programs by Trench (2008) must be combined. When used together, these frameworks link the participants' worldviews with their opinions on how science communication should be conducted. In this phase of the research, it appears that belief in the dissemination model of science communication is consistent with the post-positivist worldview and the surrounding culture that the participants described.

According to the participants, science communication needed to convey research so that the audience would understand both established facts and “big questions” in science. The audience also needed to appreciate science and its language, and know that scientists did not always have the answers. In other words, the participants wanted to communicate both scientific research and the nature of scientific research to the lay public. They wanted the people communicating the science to know how to talk to lay audiences and simplify scientific facts. These views are rooted in the post-positivist worldviews of the scientists as well as the culture in which they are working.

First, the researchers want the public to be knowledgeable about the nature of scientific practice. The researchers wanted the public to know that science does not always have all the answers, and that statistics are only estimates and hence many of the findings that are published can still change. The researchers were fully recognizing their epistemological beliefs and their limitations as scientists and using them as tools to inform the public about the true nature of science. The view of a limited science is consistent with the views of post-positivism. The researchers' values of integrity and honesty, as well as the norm of truthful communication, are all consistent with their interpretation of the dissemination model of science.

Second, the researchers believed that they owed society communication because society was paying for research. The researchers also spoke of how science had always helped society, and if it were not for science, society would not have progressed to the state that it is in now. This belief in the integration of science with society is consistent with the researchers' post-positivist beliefs, and their perceived debt to society is consistent with their norms and values. Moreover, their belief in science as the savior of humankind is consistent with the dissemination model, where scientific knowledge is held in highest regard. This is especially evident when the scientists talk about an anti-intellectual public that has made enemies of knowledge and understanding. This is also mentioned when the researchers talk about communication that pushes emotional buttons or that misleads the public, both of which clash with the epistemological beliefs that the scientists hold, and both of which run counter to the superior knowledge that science should provide.

Fourth, the researchers believed that simple language and truth were necessary in order to carry out good science communication. This is consistent with the epistemological belief in the superiority of scientific knowledge, as well as the dissemination model, where the public is viewed as ignorant and therefore simply needing good facts in a language at their level.

The researchers, therefore, carry out science communication in order to dispel the public's perception of the science *that appears to be*, and to replace it with the science that *is.* The participants want the public to recognize that scientists truly do not agree with each other and knowledge will change because science is built to be tentative. In order to carry out such communication, the researchers need to deal with a media that sets facts in stone, a public that expects scientists to behave the way they do in the movies or in textbooks, and funding agencies that do not seem to appreciate the epistemological beliefs of researchers. Nevertheless, the researchers are firmly rooted by their worldviews and culture, and are thus able to deal with the pressures.

To conclude this section of the discussion, it appears that the researchers' post-positivist worldviews, as well as their culture, all contribute to how they regard the task of science communication. Thus, the combined Guba and Lincoln (1994) and Trench (2008) frameworks is valuable, not only in finding out what the worldviews and cultures of scientists are, and not only in finding out what science communication model they believe in. The combined framework can contribute to a deeper understanding of: (a) why the researchers’ worldviews are structured in a certain way and (b) why they believe in a certain model of science communication.

For a deeper understanding of their role in science communication, the researchers must be understood in terms of what they perceive to be the new culture of science, what they perceive to be their tools in dealing with this culture, and how they define their role in science communication relative to other participants in the science communication process. To carry this out, a combined framework must be used to explore their culture and the boundaries that they set.

A combined framework of culture-as-toolbox and boundary setting.

A deductive analysis of the interviews and field notes from the U.S. phase suggested that the participants perceived a change in the current science research arena. They believed that scientists needed only to write grants, get their work published, be funded, and do basic science. In the current time, participants were also expected to communicate honestly with different audiences because they were the experts. They also needed to deal with funding issues, a media that misinterpreted and misrepresented them, and a public that did not trust or understand science. The participants recognized that they needed to communicate, but they did not like to work with the mass media, and they did not express any wish to work with social scientists. However, they expressed their wish to communicate directly and work with the lay public.

In this subsection of the discussion, Swidler's culture-as-toolbox model (1986) is combined with Lam's boundary-setting framework (2010) in order to gain a deeper understanding of the science communication culture, and what the participants believe their role is in science communication.

The way that science communication was being conducted clashed with the participants' epistemological beliefs. However, these same epistemological beliefs provided them with the tools to carry out what they perceived to be good science communication. These tools included the social nature of scientific practice, the expertise and credibility of participants, and the participants' teaching experience, Moreover, the participants believed that they needed more tools in order to succeed. These tools included communication training, intermediaries, and a need to understand how science is learned and communicated.

The players in science communication, according to a majority of the participants, included the researchers themselves, the lay public, and knowledge brokers. These knowledge brokers included the mass media and what the participants called "intermediaries." The participants' attitudes to these different players were likewise different. Each player had a role in the new science culture, and each role can be understood when the boundaries between them and participants are investigated further.

When dealing with the public, a majority of the participants were Communicating Hybrids. They were aware of their social obligations to communicate, but they were aware of their obligations as scientists as well and did not experience any role identity tension. When they talked about how and why they communicated with the lay public, the participants invoked their epistemological beliefs, norms, and values of science, where they had obligations to serve science by communicating their work truthfully. This truthful communication also entailed discussing how tentative science was, as well as communicating the excitement that they experienced as scientists. This communication content is consistent not only with the participants' epistemological beliefs, but their desire to make the lay public understand these epistemological beliefs as well. Science communication, therefore, was a tool for the public to understand the nuances of science, along with the facts as the participants knew them at the present time.

However, on the whole, the participants kept tight boundaries between themselves and the media. They admitted to not wanting to work with the media, and even if they did, they wanted their work to be limited to checking media coverage for errors. The participants wanted the media to change its portrayal of scientists so that the public would likewise change its perception of scientists. Some of the participants wanted to work with intermediaries instead of dealing directly with what it perceived to be a hysteria-driven mass media. They believed that they remained the source of knowledge and would thus simply be consulted by intermediaries when time came to communicate about science. None of the participants expressed any need or desire to work with social scientists. Some participants appreciated the difficulty of social science work, but most of the participants remained skeptical. The boundaries that they drew between the bench scientists and social scientists, therefore, were not as well defined according to the Lam (2010) framework.

The participants also criticized how science communication was being conducted. They believed that the media pushed emotional buttons, spread fear and lies, and therefore confused the public. The public, for its part, believed in the media. Therefore, the public was anti-science and remained ignorant about many scientific principles. Moreover, because people did not appreciate the science that *is*, they did not trust scientists when scientists showed the true face of science: one where scientists disagreed, and one where the facts were not final.

The participants' opinion of what constitutes flawed science communication can be traced to their belief in the tools of science. Using the Swidler model (1986) of culture-as-toolbox, these tools allowed scientists to deal with the increasing demand for them to communicate their findings. In particular, the participants called on their epistemologically-rooted norms and values to deal with the changing science culture.

The participants' critique of the mass media can also be traced to the influence of their science culture. Because the media played on the emotions and spread fear and hysteria, it was also lacking in objectivity. Because the media did not convey facts, or conveyed tentative facts with finality, it ran against the values of honesty and knowledge, and against the epistemological beliefs that dictated the tentativeness of scientific facts. The media also presented findings from only one study, or abused facts, which run contrary to the participants' values of honesty and integrity, and the epistemological belief that research must be replicated using good methodology.

Moreover, the participants, for the greater part, wanted to have some involvement in science communication. They wanted to speak, in fact, before the non-experts did. Their insistence on direct or near-direct communication can also stem from their belief in the superiority of scientific knowledge, integrity and honesty, and their need to communicate truthfully. This need to be consulted for scientific input is also consistent with the participants' belief in the dissemination model.

It is interesting how the participants have less tight boundaries between themselves and the lay public, compared to those that they set between themselves and the mass media. This might be due to the fact that the participants have an epistemologically-rooted belief that they are tasked to serve society. This might also be due to the fact that their clashes with the mass media are epistemologically-rooted as well. Hence, the participants tend to tighten and close their boundaries between themselves and the mass media, especially when they find that they can get nothing out of the interaction except misrepresentation and misinterpretation.

Using the Lam (2010) scheme to categorize the boundaries between the participants and social scientists was difficult because the participants did not express any need to work with social scientists – but at the same time, they did not express any explicit abhorrence of dealing with social scientists as well. It appeared as though they believed that social scientists were scientists as long as the social scientists worked with the tools and approaches of the bench sciences. Because both groups were working on the same field, but on different data, it appeared that the participants in this study did not feel any connection to the social scientists other than as providers of tools that social scientists could use to make their research better.

Despite these shortcomings of the Lam (2010) scheme, the combined Lam (2010) and Swidler (1986) schemes can provide an even deeper view of the current science culture. Without using the Lam (2010) framework, the Swidler (1986) framework might make it appear that the only persons responsible for communicating science are scientists, who, in turn, feel as though they are being attacked at all sides by the lay public, politicians, and mass media. Without the Swidler (1986) framework, the Lam (2010) framework will only have a description of the boundaries that scientists draw around themselves without a reason as to why such boundaries are even present.

Through the eyes of the Swidler (1986) framework, the science communication culture might appear to be in trouble, but the participants believe that they have tools that will not only help them communicate to the public, but communicate the science that *is* as well. Through the eyes of the Lam (2010) framework, the researchers might appear to consultants or knowledge providers for society, and science appears to provide the tools that will help all of society move forward. Using all these findings, it appears that participants call upon their epistemological beliefs in order to function in the new science culture, and likewise expect that such beliefs will help the rest of the players in science communication move the field forward.

The participants were aware of their obligations to communicate their findings to society. They had training as scientists and their epistemological beliefs allowed them to deal with the difficulties of science, as well as point out the shortcomings of the public and the mass media. These epistemological beliefs, as well as tools and approaches were also useful, they believed for progress in other scientific fields.

A General Discussion of Both Cultural Contexts

Despite the need to examine both the cultural contexts on their own merits, a comparison cannot be avoided. First, in both contexts, it appears that the combined framework of worldviews, culture, and science communication was able to draw out the participants' beliefs and how such research and science traditions contributed to the participants' opinions of science-related fields. The combined framework was also useful in adding philosophical foundations to the Trench (2008) framework, which is largely typological and aims to identify rather than explain participants' communication beliefs. This combined framework can be the basis of theory in science communication, as it allows philosophical and cultural beliefs to explain researchers' communication beliefs.

On the other hand, the combined culture-as-toolbox and boundary setting framework was not as successful in parsing out the boundaries that researchers set between themselves and other players in the science communication arena. The combined framework was able to delineate the boundaries that researchers set between themselves and the lay public, however, and it was evident that the participants wanted to serve the lay public without having to deal with the mass media. In the U.S. phase of the study, it was likewise evident that the epistemological beliefs of scientists contributed to their need to serve society, but also contributed to how they wanted to avoid working with the mass media. The same phenomenon was difficult to see in the Philippine arena, which may be due to the fact that the Filipino participants were dealing with a different culture and were experiencing their own brand of clashes with the lay public and the mass media.

The worldviews and science cultures of the participants in both the contexts could be seen as their own coping mechanisms when they were faced with the cultures that surrounded them. The dual positivist/post-positivist worldview espoused by participants from the Philippines was their own way of dealing with a society that they believed was not thinking scientifically, and that had bad cultural habits that prevented science from flourishing. The Philippine culture was also less assertive and critical by nature, which prevented practice of some research norms.

The post-positivist worldview espoused by some U.S. -based participants could be due to their socialization into science and the surrounding culture, which encouraged creativity and critical thinking. The positivist worldview espoused by two of the U.S.-based participants could be attributed to their experiences with the media and funding agencies; hence, they needed to reassert their boundaries and cling to the traditions of science.

In both cultural contexts, the science worldviews and cultures were needed in order to cope with society at large. In both cultural contexts, moreover, participants espoused some common worldviews, values, and norms. The participants all believed in objectivity, although they had different definitions of it. They all believed that scientists needed to serve the lay public, as well as communicate truth to the lay public. The contents of that “truth” however, were different: to Philippine participants who were based in a culture that did not encourage their work, they believed that simply giving facts to the public would excite the public the way that science had excited them in school; to U.S.-based participants who were based in a culture that encouraged creativity but were mistrustful of scientists, they believed that showing the true face of science to the public would allow the public to see how facts could be understood only against the backdrop of the true nature of science.

Moreover, both sets of participants believed in the dissemination model of science communication, and largely because they held scientific knowledge in high regard. Again, the differences were in the nature of the knowledge being disseminated.

The cultures that surrounded the participants were also very different. The Filipino participants were able to talk about many cultural habits that they believed were standing in the way of science, such as lack of commitment to long-term work, politics, lack of assertiveness, and crab mentality. Only one American scientist, Jessica, believed that the American culture sometimes encouraged going straight into solving problems without any thought. It seemed that the Filipinos were quick to point out their faults while the U.S.-based scientists were quick to see the advantages that their culture posed.

Another trend that ran through the interviews was the fact that some of the Filipino participants believed that the Philippines had no science culture, while the U.S.-based participants believed that the science culture was so diverse that it could not simply be explained in a brief amount of time.

In both cultural contexts, the participants were willing to communicate with the public directly as communicating hybrids, but were not willing (or were hesitant) to deal with the mass media. In both cultural contexts, the participants were willing to rely on the work of intermediaries to carry out science communication. The tools that researchers used in both cultural contexts were almost the same as they talked about dealing with science communication, except that the Philippine-based participants were intent on providing facts within context, while the U.S.-based participants wanted to talk about why science was the way it was. Again, the difference was in content, but both groups of scientists still wanted to be the source of knowledge for the lay public.

Another cultural difference was the fact that some Philippine-based scientists acknowledged that social scientists were contributing to the knowledge base and were therefore needed for science to be accepted by the lay public. No such sentiment was echoed by the participants in the U.S. phase of the study: they simply talked about the social sciences as another field of learning, but expressed no desire to work with them. They acknowledged that the data was harder to trust and work with, but they did not say anything about how the social sciences could help in social acceptability, or in any other way in assistance to the bench sciences.

Such a difference might be explained by the funding situation. First, the Filipino scientists were operating in a funding atmosphere that encouraged social sciences work and social acceptability studies alongside bench science work. Hence, the Filipino scientists felt compelled to work with social scientists, or at least say that they wanted to work with social scientists. On the other hand, U.S.-based scientists were working in a funding atmosphere that gave funding to research that was high-impact, with positive results, which meant that research work concentrated on the contribution of bench researchers alone. The social sciences, therefore, despite their contribution to knowledge, were not necessarily part of the researchers' work.

Another cultural difference was found in how most of the Filipino participants attributed their initial interest in science to a family member, whether it was relatives who were in the sciences, a father who encouraged them to ask questions and investigate, or a mother who wanted them to earn more money for the family. On the other hand, U.S.-based participants were first interested in science because of hands-on work, a mentor or teacher, or growing up in an atmosphere that encouraged science. This difference might be due to the fact that Filipinos are family oriented, while independence is encouraged in U.S. families. However, these assessments are anecdotal and should be substantiated by further research.

Participants in both cultural contexts acknowledged that religion was separate from science. However, some of the Filipino scientists admitted to being very deeply religious and felt that their scientific work had been supported by religion, while many of the U.S.-based scientists were not religious. The only person who admitted to religion being instrumental in her life was Queenie, who had only come to the U.S. within the last decade from a West Asian country.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This chapter is divided into two major subsections. In the first subsection, Conclusions, a summary of the findings of the research will be presented, followed by conclusions on these findings. The Conclusions subsection will also make assertions regarding how researchers from the two cultures can learn from each other, and what they hold in common. This will be followed by recommendations on how the findings of the research can be useful to science communication researchers, mass media, science communication professors, and scientists. In the next subsection, recommendations will be made for future research.

Conclusions

In conclusion, this research has found various views of the scientific discipline, science culture, and science communication unique to two different cultural milieus. A deductive analysis of the interviews and field notes from the Philippine phase suggested that participants espoused a joint positivist/post-positivist worldview. They valued honesty, openness, passion, love for knowledge, mental capacity, and the societal impact of their work. They practiced the norms of objectivity, collaboration, hard work, mentoring, updating one's knowledge base, creativity, systematic work, research productivity, and publishing or communicating. They disapproved of overconcluding or overinterpreting data, dishonesty, secrecy, laziness, lack of objectivity, and copying other participants' work, which, the researchers believed, would bring the field to a standstill and even place lives at risk. The participants reported that they had been socialized through years of school and training, but they also recognized that the science that they had learned in school was different from how it was truly practiced.

The participants also reported working in a surrounding culture that impeded the growth of science. This was partly due to cultural habits such as oversensitivity and lack of assertiveness, politics, colonial mentality, crab mentality, and lack of commitment to long term work. Lack of funding exacerbated the cultural traits that made science difficult to practice in the Philippines. However, the participants also believed that several Filipino traits could make Filipinos good researchers. These included traits such as resourcefulness, a strong family background, faith, and a culture that allowed females to advance in their careers. They also believed that Ph.D. training abroad removed any poor Filipino cultural traits. The participants also described themselves as being religious but many believed this was a personal choice and did not affect their science.

According to the participants, the way that science communication was being conducted in the Philippines clashed with the traditions of science, but the participants believed that their science training had given them tools to cope with the need to communicate science, and the poor science communication culture. These tools include the values of honesty, the love of knowledge, and openness; and the norms of objectivity, research productivity, and publishing. Nevertheless, the participants believed that they needed more tools to improve science communication, such as the research carried out by social scientists, working with science communicators, and communication training.

The players in science communication, according to a majority of the Filipino participants, included the participants themselves, the lay public, and knowledge brokers such as social scientists and science communicators. When communicating with the public, a majority of the participants could be categorized as Communicating Hybrids. That is, they were open to public feedback on their research, and they were open to interactions with the lay public; in their openness, the researchers did not perceive any role tensions between their work in the academe and their work as civic researchers. However, the boundaries that participants set between themselves and knowledge brokers, such as science communicators and social scientists, were not as definitive.

Deductive analysis of the interviews and field notes from the U.S. phase suggested, with a few exceptions, that the participants practiced and espoused a post-positivist worldview. The participants valued advancing knowledge and the scientific field, objectivity, ethics, having an impact on society, rigor and good experimental design, integrity and honesty, and passion for learning. They practiced the norms of open-mindedness, critical thinking, admitting one's mistakes, careful and systematic work, asking questions and exploring, learning and establishing a firm knowledge base, truthful communication, working on high-impact research, accepting that there would disagreements among scientists, and mentoring. The participants disapproved of data manipulation, losing creativity, losing critical thinking, plagiarism, and sacrificing integrity for money, which, they believed, would destroy a researcher's career and reputation. The participants, on the whole, described their work in science more as a hobby than a job. They recognized that they had common traits that might make it difficult for them to communicate with or even relate to the lay public. They had been socialized through years of school and training, but they also recognized that the science that they had learned in school was different from how it was practiced.

The researchers also work in a surrounding culture that constrained what they believed to be good research behavior. These cultural aspects included funding pressures, abuse of facts by politicians, poor mass media work, and an anti-intellectual lay public. They believed that religion could inspire some questions or direct them toward some research problems, but they did not believe that it should affect how individual scientists worked. Some participants also believed that the American culture emphasized creativity and recovery from failure, which they believed were traits that were valued in research, and which they sometimes did not find in other cultures.

The participants recognized that they needed to communicate with the public, but they did not like to work with the mass media, and they did not express any wish to work with social scientists. However, they expressed a desire to communicate directly and work with the lay public.

In conclusion, collective findings from this research suggest that the cultures surrounding researchers can affect their worldviews and what they perceive to be their science culture. These worldviews and science culture, in turn, contribute to how the researchers regard the task of science communication, their perceptions of the mass media and the lay public, and the boundaries that they draw between themselves and other players in the science communication arena. The participants' worldviews and cultures were also seemingly adapted to the culture in which they worked.

The combined Guba and Lincoln (1994) and Trench (2008) frameworks proved valuable in understanding how the worldviews and cultures of researchers contribute to their views on science communication. The researchers' worldviews, science culture, and surrounding culture were consistent with their opinions on how to conduct science communication. Their worldviews, science culture, and surrounding culture also provided a sociological base to their beliefs on how science communication should be conducted. To some extent, the Swidler (1986) and Lam (2010) frameworks can also be used in order to construct the science communication culture and the participants' perception of their role in the culture. The Swidler (1986) and Lam (2010) frameworks were of limited value in this research, however, because the Lam (2010) framework could not completely assess the participants' perceived relationships with knowledge brokers, such as the mass media, social scientists, and science communicators. This may have been due to the researchers wanting to work directly with the lay public instead of with knowledge brokers. This may also be due to the researchers expressing that they wanted to change how knowledge brokers behaved, instead of talking about how they could work together with knowledge brokers in science communication.

The findings of this research provide several interesting facets of the lives of Filipino and U.S.-based researchers.

In all the frameworks used, it truly appears that there is no single scientific culture. There might be common norms and values across national cultures, but science can be different across national lines due in part to the cultural forces acting upon it. Nevertheless, there is common ground among researchers.

Both Filipino and U.S.-based researchers are passionate about science and hold the enterprise in high regard, even when they have limited resources to carry out research work. They want the lay public to share their passions and values, and they want the lay public to trust them. To the Filipino participants, the public needs help understanding science, so laypersons must be given facts. To the U.S.-based participants, the public is hostile and confused because it does not understand the nature of scientific research, and laypersons must be taught about the nature of scientific research.

Even with their commonalities, there are still interesting contrasts between the two cultural groups. For one, Filipino participants tended to believe that social scientists were needed to help encourage public acceptance of science. They were also sometimes very passionate about their faith and even linked it to their scientific practice. Filipino researchers also did not see gender as an issue. An interesting aspect of the Filipino researchers is that in their personal accounts of their socialization into science, fathers and mothers influence children differently. For instance, a father figure seems to have pushed the young participants into science due to an academic background or exposure to science-related environments, while a mother figure influenced young researchers to pursue a science-related field due to economics. While the sample sizes for making such a claim are very small, these are trends to be explored in future research, as elaborated on in the next subsection.

The challenges that researchers face are also unique to their cultural contexts. For Filipino participants, the lack of a science culture in the lay public and a poor economy lead to fewer people pursuing careers in the sciences. Such a case is tragic when one considers the unique physical and environmental characteristics of the Philippines, such as weather, topography, geology, and biodiversity, all of which call for research. However, roughly equal numbers of Filipino men and women are scientists, and limited funding has led to increased resourcefulness among many researchers. These unique aspects of the Filipino research culture should be explored in future research, and their outcomes could help U.S.-based researchers with their own problems, such as fewer females in the sciences and development of strategies to cope with limited funding.

On the other hand, U.S.-based researchers must contend with partisan politics and an anti-intellectual culture. However, they are raised in a culture that encourages creativity. In addition, compared to researchers in other countries, U.S.-based researchers generally have better facilities and more funds at their disposal. The value placed on creativity and the strong science culture that might serve as a model and an inspiration to advance science in the Philippines.

The findings of this research provide valuable lessons of use to different players in the science communication arena. First, there is no single culture of science, and scientists themselves are unique products of their culture, training and environment. Scientists' deeply-held, culturally-rooted beliefs should be explored in greater detail in order to understand and avoid some of the common problems in science communication. Difficulties amongst the players in science communication may often result from a clash of cultures, a clash of values, a clash of norms, and a clash of epistemological beliefs. Dialogue and discussion must be encouraged to facilitate cooperation and trust amongst the key players in science communication – scientists, communicators and the public. The need for dialogue and discussion is particularly urgent in our times. The news and media frequently focus on are filled with science-related issues that require the expertise of scientists.

The findings of this research can also be used to build theory in science communication by providing combined frameworks as guides for exploring the science communication culture; and by providing a tested interview protocol that can be used to study scientists in other cultures. The frameworks used provide a way to root researchers' responses and opinions in their worldviews, the culture of their field, and the culture with which they are surrounded. Thus, this research provides conceptual frameworks that can guide and focus future research in science communication. Such research can also help advance theoretical modeling in the context of science communication.

The findings of this research may also find application in advancing science education. Being aware of one's biases in research can allow students in science to understand what assumptions they hold in their research. For instance, a study by Buffler et al. (2009) shows that how students view the nature of science also affects what they consider to be valid measurements. Students who believed that science aimed to discover the laws of nature were more likely to think that measurements were aimed at obtaining true values; students who believed that scientists formulated theories, constructed them through observations, and then validated them through experiments were more likely to view measurements as uncertain (Buffler et al., 2009). This implies that science educators should also focus on teaching the nature of science in the classroom. For instance, they can show that researchers have their own biases that could affect how research findings are interpreted. Science educators can also show that researchers from various cultures can behave and reason about science differently. This can allow future students to examine scientific knowledge with a more critical eye.

As mentioned by some participants in their reactions to the interview, exploring their opinions about science allowed them to clarify their own philosophies about their work. Clarifying one's philosophies on science, as well as critically examining the assumptions that one holds in science, can benefit students of science. By closely studying the culture of science and the assumptions that scientists hold, the next generation of students will not only learn the facts of science, but be more knowledgeable about the nature of research and the scientific discipline. This awareness can provide them with a more realistic view of how science is practiced, versus the facts-based, absolute science that current education provides. In other words, this awareness might allow future scientists – and even future students, in general – a much deeper glimpse and therefore greater appreciation for the science that *is*, versus the science that *appears to be*.

The findings and tools used in this research may also be used for communications training programs for scientists. The participants in this research knew that science communication and risk communication had a goal of disseminating information, and could be influenced by stakeholders. However, they also wanted to change people and turn lay persons into scientists. Such a view can be difficult for future students of science, because such a goal is not central to science communication and is not shared by all stakeholders. Scientists can be made aware of their own assumptions about the world, the scientific discipline, and the lay public. With greater awareness of their assumptions, scientists can work more effectively with social scientists, science communicators or intermediaries, and the mass media as they understand how to communicate better with the lay public. Training scientists in science communication is not only about telling scientists how to communicate science, but why it is done in certain ways.

However, it is not only scientists who could benefit from training. Professors who teach science communication should revisit current methods of instruction. Rather than being viewed as an end result, a message, or a visual, science communication may best be conceptualized as an ongoing, complex process. This view of science communication complicates the task well beyond simplifying language or increasing readability for the masses.

Current science journalists should also be aware of how culture can influence how scientists act, and how scientists are influenced by both a national culture and a science culture unique to their disciplines. This study cannot make generalizations on the basis of national cultures, but it is nevertheless apparent that there are differences amongst scientists from different national cultures. Science communicators in training and science journalists must be aware of these differences and how these differences can play into how scientists interact with science communicators.

Despite the current researcher's view that science communication can and should be improved, this research should not be thought of as a tool for advocating communication work for all scientists. Rather, this work has a goal of uncovering why scientists think and behave in certain ways, and why they may choose to communicate or not. This research is a tool for understanding scientists, and for scientists to understand themselves.

Recommendations for future research

This research aimed to investigate the many perspectives of researchers from different fields. However, there might be nuances among research fields, in age groups, or even in gender groups that have not been brought to light yet. This research should be replicated with researchers from other countries and cultures, but with some modifications. The interview tool can be used for various purposes, whether to analyze a large population size of researchers from one culture, or a small population size of researchers from a single field. To continue the current research, the interview tool can be used to analyze the views of U.S.-based Filipino-born scientists and compare these views with Filipino-born scientists based in the Philippines. The interview tool can also be used to interview and analyze populations of female scientists or engineers, or compare the views of experienced researchers with the views of less experienced researchers. The interview tool can also be used to analyze populations of social scientists.

The questions can be retailored in order to fit the culture of scientists or engineers. These are two very different fields and cultures, as some of the participants indicated. Hence, each field must be studied in depth.

Some participants also wanted to be asked more direct, specific questions. The participants themselves suggested additional questions that could provide deeper insight into the opinions of scientists such as: how much are scientists paid? Or what are the reward systems of science? What happens when scientists disagree with each other? How are male and female scientists different?

The shortcomings of the Lam (2010) scheme could be used to expand or modify it to include the professionals who work alongside scientists, such as industry persons, mass media, science communicators, and social scientists. The new scheme should ask what changes scientists want in their collaborators, and why such changes are needed. The new scheme should also ask whether scientists want to be directly involved in publicizing their research through channels other than traditional peer review. The researchers should also be asked about their views on collaboration: who should be involved in a collaborative effort, and what are the roles of these different collaborators?

The expanded Lam (2010) scheme can be useful when designing collaborative projects that include natural sciences and social sciences components. If bench scientists are aware of the assumptions that they have regarding the mass media, science communicators, intermediaries, social scientists, and other collaborators, then better cooperation might be achieved amongst all parties involved in the project.

The participants' responses also provided intriguing avenues for future research. For instance, a deeper investigation of how religion affects researchers in different culture can uncover more opinions regarding religious belief and how it matches – or does not match – scientific beliefs. Research into the influence of the researchers' parents can be useful when investigating how researchers are socialized early on into their respective fields. An investigation as to why Filipina participants do not perceive discrimination in their careers might also be useful when investigating the Filipino culture further. Research into the perceived roles of social scientists might uncover why U.S.-based scientists did not express a need to work with them for social acceptability of research.

Some of the participants also claimed that speaking about themselves allowed them to clarify their philosophies and assumptions about their work. While such findings might appear to be more personal than scholarly, they can perhaps encourage future research in the nature of science from the point of view of scientists. Clearer philosophies and an awareness of the assumptions that one holds could perhaps translate to better science education and scientific work. Moreover, the use of such a research tool might allow scientists to know themselves and their discipline in even greater depth.

Finally, the research protocol used in this study can allow for theory building in the field of science communication. With new theories to guide the field, additional scholarly research can be conducted to place science communication on even stronger empirical foundations.

Research findings and analyses reported here add to the knowledge base about researchers and their views of science and risk communication. However, in uncovering the cultural and worldview roots of these views, and in defining the elements of the science communication culture, more issues emerge. Science communication, as a field, now has some basis for theoretical foundations, but there are many avenues for research that must be examined further, and work must continue so that the discipline can grow and flourish. With theory-driven research, science communication can reach its fullest potential, and the lay public will have trustworthy scientific knowledge that will help them make informed decisions on various science-related issues in their day-to-day lives.

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APPENDICES

Appendix A. Recruitment Letter for Filipino Participants

<Name>
<Address>

Dear Dr. _________,

Greetings!

I am Inez Ponce de Leon, a graduate student from Purdue University. I was able to find your e-mail address through <website or online directory of researchers>. I believe that your research in <research interests of contact> and your years of experience can contribute not only to the growth of science in the Philippines, but to an understanding of the dynamics and nuances of the scientific culture and science communication in our country.

I would like to interview you for my research. I will interview researchers from both the United States and the Philippines, and explore their views on science communication and the science culture. My interview with you will contain the following general questions: what made you pursue science as a field? What is a scientist? What is the role of science? What is the scientific culture like? What methods do you use in your research? How do you define science communication? I will also ask you follow-up questions related to these major interview questions.

I will be recording the interview using a digital audio recorder, but I promise that I will keep your identity and contact information strictly confidential. This study is strictly voluntary, and if you encounter questions during the interview that you do not wish to answer, then you do not have to. Moreover, the location of the interview will be entirely of your choosing: I would like this interview to be as convenient, and as enjoyable for you as possible.

I hope that you will reply positively to my request, and I hope I can hear from you soon! If you have any questions, and if you would like to accept my invitation for the interview, please do not hesitate to send me an email at inez.poncedeleon@gmail.com, or give me a call at ___________________.

Thank you very much, and best wishes!

Sincerely,

Inez Ponce de Leon
Graduate Student
Department of Youth Development and Agricultural Education
Purdue University
West Lafayette Indiana

Dr. Mark Tucker
Associate Professor
Department of Youth Development and Agricultural Education
Purdue University
West Lafayette Indiana

Appendix B. Scheduling Letter for Filipino Participants

<Name>
<Address>

Dear Dr. _________,

Greetings!

Thank you very much for your positive response to my invitation!

To reiterate, I would like to understand the scientific culture, and my current research is on how Filipino and American researchers articulate their opinions on science, researchers, scientific methods, and science communication. By asking researchers about their opinions, I hope to contribute to the growing body of literature in science communication and the nature of science.

Our interview will be at a place of your choosing. I hope that this will make you more comfortable as you answer my questions. In general, my questions will be on the practice of science, the discipline itself, your work as a scientist, your culture, and your views on science communication.

Would you be available for an interview on (DATE), at (TIME)? Again, I will be recording our interview using a digital audio recorder, but your identity and contact information will be kept strictly confidential. When I transcribe our interview, I will use only a pseudonym in place of your name.

If you have any questions, and if you would already like to schedule the interview, please send me an email at inez.poncedeleon@gmail.com, or call me at ________.

Thank you very much, and best wishes!

Sincerely,

Inez Ponce de Leon
Graduate Student
Department of Youth Development and Agricultural Education
Purdue University
West Lafayette Indiana

Dr. Mark Tucker
Associate Professor
Department of Youth Development and Agricultural Education
Purdue University
West Lafayette Indiana

Appendix C. Recruitment Letter for U.S.-based Participants

<Name>
<Address>

Dear Dr. _________,

Greetings!

I am Inez Ponce de Leon, a graduate student from Purdue University. I was able to find your e-mail address through <website or online directory of researchers>. I believe that your research in <research interests of contact> and your years of experience can contribute not only to the growth of science in general, but to an understanding of the dynamics and nuances of the scientific culture in particular.

I would like to interview you for my research. I will interview researchers from both the United States and the Philippines, and explore their views on science communication and the science culture. My interview with you will contain the following general questions: what made you pursue science as a field? What is a scientist? What is the role of science? What is the scientific culture like? What methods do you use in your research? How do you define science communication? I will also ask you follow-up questions related to these major interview questions.

I will be recording the interview using a digital audio recorder, but I promise that I will keep your identity and contact information strictly confidential. This study is strictly voluntary, and if you encounter questions during the interview that you do not wish to answer, then you do not have to. Moreover, the location of the interview will be entirely of your choosing: I would like this interview to be as convenient, and as enjoyable for you as possible.

I hope that you will reply positively to my request, and I hope I can hear from you soon! If you have any questions, and if you would like to accept my invitation for the interview, please do not hesitate to send me an email at inez.poncedeleon@gmail.com, or give me a call at __________________.

Thank you very much, and best wishes!

Sincerely,

Inez Ponce de Leon
Graduate Student
Department of Youth Development and Agricultural Education
Purdue University
West Lafayette Indiana

Dr. Mark Tucker
Associate Professor
Department of Youth Development and Agricultural Education
Purdue University, West Lafayette Indiana

Appendix D. Scheduling Letter for U.S.-Based Participants

<Name>
<Address>

Dear Dr. _________,

Greetings!

Thank you very much for your positive response to my invitation!

Our interview will be at a place of your choosing. I hope that this will make you more comfortable as you answer my questions. In general, my questions will be on the practice of science, the discipline itself, your work as a scientist, your culture, and your views on science communication.

Would you be available for an interview on (DATE), at (TIME)? Again, I will be recording our interview using a digital audio recorder, but your identity and contact information will be kept strictly confidential. When I transcribe our interview, I will use only a pseudonym in place of your name.

If you have any questions, and if you would already like to schedule the interview, please send me an email at inez.poncedeleon@gmail.com, or call me at ________.

Thank you very much, and best wishes!

Sincerely,

Inez Ponce de Leon

Graduate Student
Department of Youth Development and Agricultural Education
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Dr. Mark Tucker
Associate Professor
Department of Youth Development and Agricultural Education
Purdue University
West Lafayette Indiana

Appendix E. Interview Questions for Participants in the Philippines

1. Icebreaker – to set tone of interview

- Demographic questions: How old are you? What is your marital status? (For married participants) How large is your family? What is the highest level of education you have completed? Where did you complete your Ph.D. and what was your research about? What is your employment status? How long have you been at your current job?
    - What made you pursue science/engineering?
    - How long have you been interested in science/engineering?
    - What first piqued your interest in science/engineering?
    - Where were you trained?
    - What is your expertise?
    - What is your current research?

2. The Image of a Scientist

- How important was a mentor in your research and training?
- What are the responsibilities of a scientist/engineer?
- What is the job of scientists/engineers?
- What, to you, is a successful scientist/engineer?
- What should scientists/engineers be or do in order to be successful?
- What should they not do or not be if they want to be successful?
- I have heard that there are only a few scientists in the Philippines, and I always thought we had a lot. Who would you classify as a scientist? How is the term "scientist" defined?

3. The Nature of Science

- What was science/engineering like for you when you were studying it in school?
- How did science/engineering change for you when you entered the professional world?
- What are the responsibilities of science/engineering?
- What is NOT science? For example, if you were to hear something or see something on TV, what would make you go, "That's not scientific – I'm not listening"?
- What about the social sciences? Are they scientific too? Why or why not?
- Is science/engineering free from outside influences, like politics? Why or why not?
- Should it be free from these influences? Why or why not?

4. The Culture of Science

- There is a Filipino culture, and Filipinos share some things in common. We have our fiestas and our traditions, or shared values and beliefs. Is there also a scientific culture? What is it like?
- How does your background culture affect the way that you do your work?
- What other things, aside from culture, affect your work?
- What is your life like outside the laboratory?
- How do these other pursuits affect what you choose to do research in?
- How do these other pursuits affect how you do your research?

5. The Nature of Scientific Inquiry

- What kinds of data are considered scientific?
- What makes a method scientific?
- How is scientific work unique?
- What scientific method do you use when gathering data and doing your research?
- Do social scientists do the same things as you do in their research? Why or why not?
- Should scientists/engineers always be objective? Why or why not?
- What to you is objectivity?

6. Science and Risk Communication

- Have you heard of the terms “science communication”? (If yes) How would you describe/define science communication? (If no: define for participant)
- Have you heard of the terms “risk communication”? How would you describe/define risk communication? (If no: define for participant)
- What should science and risk communication aim to do for its audience?
- Should researchers be involved in science and risk communication? Why or why not?
- What do you think the public thinks of scientists?

7. Religion (to be asked only if scientist does not bring up religion earlier in the interview)

- Although you mentioned many different things about culture, you did not bring up religion. Why is that?
- Does religion have an effect on how you do your science? Why or why not?

8. Feedback

- What did you think about this interview?
- Was there anything that you had a hard time talking about? What was it, and could you tell me why you had a hard time?
- What is your overall reaction to this experience?

Appendix F. Interview Questions for U.S.-Based Participants

1. Icebreaker – to set tone of interview

- Demographic questions: How old are you? What is your marital status? (For married participants) How large is your family? What is the highest level of education you have completed? Where did you complete your Ph.D. and what was your research about? What is your employment status? How long have you been at your current job?
    - What made you pursue science/engineering?
    - How long have you been interested in science/engineering?
    - What first piqued your interest in science/engineering?
    - Where were you trained?
    - What is your expertise?
    - What is your current research?

2. The Image of a Scientist

- How important was a mentor in your research and training?
- What are the responsibilities of a scientist/engineer?
- What is the job of scientists/engineers?
- What, to you, is a successful scientist/engineer?
- What should scientists/engineers be or do in order to be successful?
- What should they not do or not be if they want to be successful?
- There are many scientists working in the U.S., and sometimes, the term “scientist” is used loosely to talk about anyone who works in a laboratory. It's a term that you hear on TV, in the press, and anywhere. But, strictly speaking, who would you classify as a scientist/what does it take to be considered or called a scientist?

3. The Nature of Science

- What was science/engineering like for you when you were studying it in school?
- How did science/engineering change for you when you entered the professional world?
- What are the responsibilities of science/engineering?
- What is NOT science? For example, if you were to hear something or see something on TV, what would make you go, “That’s not scientific – I’m not listening”?
- What about the social sciences? Are they scientific too? Why or why not?
- Is science/engineering free from outside influences, like politics? Why or why not?
- Should it be free from these influences? Why or why not?

4. The Culture of Science

- As a group, Americans have many things in common; there's an American culture, which binds Americans together. There's also a Spanish culture, a British culture, a Japanese culture, etc. What about scientists, as a group? Please describe the scientific culture that binds you together.
- How does your background culture affect the way that you do your work?
- What other things, aside from culture, affect your work?
- What is your life like outside the laboratory?
- How do these other pursuits affect what you choose to do research in?
- How do these other pursuits affect how you do your research?

5. The Nature of Scientific Inquiry

- What kinds of data are considered scientific?
- What makes a method scientific?
- How is scientific work unique?
- What scientific method do you use when gathering data and doing your research?
- Do social scientists do the same things as you do in their research? Why or why not?
- Should scientists/engineers always be objective? Why or why not?
- What to you is objectivity?

6. Science and Risk Communication

- Have you heard of the terms "science communication"? (If yes) How would you describe/define science communication? (If no: define for participant)
- Have you heard of the terms "risk communication"? How would you describe/define risk communication? (If no: define for participant)
- What should science and risk communication aim to do for its audience?
- Should researchers be involved in science and risk communication? Why or why not?
- What do you think the public thinks of scientists?

7. Religion (to be asked only if scientist does not bring up religion earlier in the interview)

- Although you mentioned many different things about culture, you did not bring up religion. Why is that?
- Does religion have an effect on how you do your science? Why or why not?

8. Feedback

- What did you think about this interview?
- Was there anything that you had a hard time talking about? What was it, and could you tell me why you had a hard time?
- What is your overall reaction to this experience?

Appendix G. Complete Codebook for Analyzing Interview Data

INSTRUCTIONS: Mark the interview data where the following typologies occur. As you mark each part of the data, describe it in the typology file. Tally themes that are repeated by other participants. When you are done with one typology, move on to the next one. Repeat until all typologies are exhausted and you have marked all the interviews.

A. Science Communication Programs and Worldviews

- **The Nature of Science** – statement on what science is, in general. This includes statements on science being objective or value-free (or anything to the contrary). Differentiate between the following sub-typologies, if they exist:
    - The nature of science as imposed by school/academe
    - The "real" nature of science, which may be based on the scientist's opinion and experiences
- **The Nature of Scientific Inquiry** – statement on what researchers think they should be doing or what they are doing. These are methods-related statements, NOT research–related statements. That is, do not look for what particular research is being done, but how the researcher articulates methods in science, in general. Differentiate between the following sub-typologies, if they exist:
    - The nature of scientific inquiry as imposed by school/academe
    - The "real" nature of scientific inquiry, which may be based on the scientist's opinion
- **The Scientific Culture** – statement on how researchers behave as a group. Unlike The Nature of Science typology, this is more people-based than it is

philosophy-based. Distinguish among the following sub-typologies, if they exist:

- **Norms of science** – what should researchers do? What are researchers expected to do? (such a statement will begin with, "Scientists are," or "Scientists usually")
- **Measures of success** – what makes a researcher successful? What are the marks of success?
- **Values of science** – what characteristics do the researchers hold as important? (Such statements usually start with, "Scientists should be" or "Scientists need to be")
- **Sanctions** – what should researchers not do?

- **Science and Society** – statement that connects science with society. This may be classified under one of the following sub-typologies:
  - The responsibilities of science and researchers
  - Should science be free from these influences of society?
- **The Researcher** – statement on how researchers should behave individually. Look for statements on behavior and characteristics. Such statements talk more about individual researchers instead of how scientists behave as a group.
- **Science and Culture** – statement on cultural factors that affect scientific practice. Differentiate among the following sub-typologies:
  - People's Perceptions of Scientists
  - Cultural Habits of the Surrounding Culture

- Funding
- Politics and Economics
- Religion

- **The Nature of Scientific Knowledge** – statement on how research data is treated and what is considered scientific knowledge and valid data
- **The Image of Science** - How do researchers regard the field of science? Is it the source of knowledge, infallible, and to be entirely trusted? Or is it only another field that must draw from other fields of study?
- **The Role of Researchers** - What role should researchers play in science and risk communication? (TAKE NOTE: This role is very specific to the communication and responses to this typology will be taken from responses to the question on whether scientists should be directly involved in communication. However, this typology may also occur in other parts of the interview)
- **The Image of the Public** - How do scientists regard the lay public? What do they think the lay public thinks of them?
- **How to Communicate Science Well Despite the Issues** - How should science and risk communication be done? What are the issues involved in communicating to the lay public?
- **The Role of Science Communication** - What should science and risk communication do for its target audience?

B. Cultural Tools and Boundary Negotiations

- **The Overarching Ideology** – What are the past dictates of science regarding science communication? What are the past dictates of science regarding scientific practice?
- **The Scientific Culture** – what was the culture of science with regard to science and science communication? Unlike the "Overarching Ideology" typology, this examines what is actually happening instead of what is ordered by science.
- **The New Ideology** – What does science communication require? What are the dictates of science communication? Who orders for things to happen in science communication? What is the ideal ideology that researchers strive for?
- **The Science Communication Culture –** What is the culture of science communication like? What is the current culture of science? What ideal culture are the researchers striving for? Unlike the "New Ideology" typology, this examines what is actually happening in science and science communication instead of what it demands of researchers.
- **Tools –** What are the researchers' tools and strategies for carrying out effective science communication? What are their tools for dealing with the changing culture of science?
- **Traditions and Common Sense** – What are the researchers' native conceptions of science and the world? How has science always been? How has the world always been?

- **Competition with existing cultural assumptions –** Note any clash between the assumptions and ideals of science and science communication. This is not about how science is practiced, but how researchers might draw contrasts between science and how their ideals clash with how science communication is being practiced.
- **The Nature of Mass communication** – What do researchers think of the mass media?
- **The responsibilities of researchers** – Collect general statements on the responsibilities of researchers
- **The responsibilities of science** – Collect general statements on the responsibilities of science
- **Boundaries between mass media and science** – is there a boundary between mass media and science? What comparisons are scientists drawing? Who is tasked to do what?
- **Boundaries between public and science** – is there a boundary between the public and science? What do scientists think about the public? What does the public think about science? How are scientists and the public different?
- **Boundaries between the mass media and the public** – is there a boundary between the mass media and the public? What is this boundary like and how are these two parties different?
- **Boundaries between the social and bench sciences –** Who is tasked with doing what job? What do the scientists or engineers think about social scientists? How are the bench and social sciences different?

- **Effects of mass media on science/engineering research** – How has science and risk communication changed or affected research?
- **Effects of mass media on the lay public** – How has science and risk communication affected the lay public? How does the mass media affect the lay public?
- **Effects of mass media on the researchers themselves** – How has science and risk communication, as it is carried out, affected the researchers personally?
- **Objectivity** –How is objectivity defined?
- **The Effects of External Forces –** What are the external forces working on researchers and/or science/engineering? Should these forces be taken away? How do these forces work?
- **Constraints on communication –** Note anything that researchers say stands in the way of effective communication
- **The Roles that Researchers should play** – Collect general statements on the roles that researchers should play. Such statements will often start with, "Researchers are the" or "The role of the researcher is to be the," or "The job of the researcher is".

VITA

VITA

I am both a bench scientist and social scientist, with training in molecular biology and biotechnology, as well as in sociology and communication. I am interested in science communication, which consists of simplifying scientific language to make it palatable and interesting to the public at large. However, there are many issues surrounding the field: what scientific concepts do we need to communicate to the public? Why should we even engage in science communication? Are scientists obligated to communicate their findings to society?

These questions indicate a need for better theorizing in science communication, which can be obtained through understanding the public, communication processes, scientists, and the scientific enterprise better. My work and current research are on the nature of science, with a focus on how scientists articulate their perceptions of their field and its obligations. In particular, I am investigating how these articulations differ across scientists from different cultures. Does a scientist's background culture affect his or her perception of the nature of science, or is there a scientific culture that transcends all cultures?

I am a writer, public speaker, and researcher, and all these activities have hitherto been related to my research interests. I have served as an advocacy and education speaker, especially in the fields of crop biotechnology and science communication. In the future, I would like to continue these activities, but on a larger level. I would like to build my own research and communication company in the Philippines, which would: a) conduct theory-based research on audience needs and perception, as well as the perceptions of scientists of various aspects of their chosen fields and b) provide quality science-based entertainment education to the Filipino audience.

Education

Ph.D.-Youth Development and Agricultural Education

Candidate
Purdue University, West Lafayette, Indiana, USA
Frederick Andrews Fellow
August 2007-present
Current Academic Average: 4.0

MS-Molecular Biology and Biotechnology

National Institute of Molecular Biology and Biotechnology
University of the Philippines Diliman
Graduated: October 2005
Academic Average – 1.21 (on a 1-5 scale, with 1 being the highest grade)

Thesis

"Analysis of Complete DNA Sequences of the Mitochondrial 16s rRNA And Cytochrome B Genes Of The Philippine Wild Pig (Sus philippensis), Visayan Warty Pig (Sus cebifrons), A Local Pig Hybrid (Sus philippensis and Sus barbatus), And Two Strains of Domesticated Hogs"

BS-Molecular Biology and Biotechnology

National Institute of Molecular Biology and Biotechnology
University of the Philippines Diliman
Graduated: March 2000
Cum laude
Academic Average – 1.597

Thesis

"Analysis of DNA from Simulated Forensic Specimens"

Professional Experience

August 2009-Present **Graduate Assistant**

Department of Youth Development and Agricultural Association
Purdue University
Duties: Research and teaching associate (AGR 201 class)

November 2000 – May 2003 **Laboratory Instructor**

National Institute of Molecular Biology and Biotechnology
University of the Philippines, Diliman

Subjects taught: molecular biophysics laboratory, cell and tissue culture lecture and laboratory, molecular microbiology laboratory, molecular physiology laboratory

September 2004-September 2006 **Science Communication Specialist**

Global Knowledge Center for Crop Biotechnology

International Service for the Acquisition of Agri-Biotech Applications (ISAAA)

Duties: science writer, speaker at various forums and symposia related to biotechnology, developer and producer of instructional materials such as pamphlets and documents related to agricultural biotechnology

2004-present **Freelance Content Writer**

Various magazines and websites

Duties: Writing on topics spanning the range of crops, fitness, foods, health, self-help, technology, and web marketing.

2004-Present **Blogger and Website Maintenance**

Official Website: http://inez.abcruz.com

Mirage Bellydancers: http://www.purdue.edu/mirage

Duties: Write short articles and diary entries, maintain the Purdue Mirage Bellydancers website

2001-present **Published novelist and poet**

Novels published through Lulu Press: Sanctuary (http://www.lulu.com/content/98621) and The Romantic (http://www.lulu.com/content/223184). Poems and short stories published in literary journal in the Philippines.

Publications and Presentations

Non-Fiction:

Editor-Reviewed Publications and Presentations

Ponce de Leon, M.I.A.Z., Hedreyda, C.T. & Gonzalez. J.C.T. (2008). Complete DNA sequence analysis of the mitochondrial 16s rRNA and cytochrome b genes of the Visayan warty pig (*Sus cebifrons*). *Asia Life Sciences: The Asian International Journal of Life Sciences, 17* (2), 295-308.

Ponce de Leon, I. (2007) For biochemistry major, lab work is 'cool.' *Destination Purdue,* Fall 2007.

Ponce de Leon, I. (2005). Fruits of the lab. *Speed Magazine*, December 2005.

Ponce de Leon, I. (2004). Fit, fat, and flippin' mad. *Avant-Garde Magazine*. June 2004.

Ponce de Leon, I. (2004). Fit, fat, and flippin' mad. *Avant-Garde Magazine*, August 2004.

Books/Book Chapters

Navarro, M., Escaler, M., Tababa, S., and Ponce de Leon, I. (2007). "The Bt Maize Experience in the Philippines: A Multi-Stakeholder Convergence." Chapter14 in "The Media, The Public, and Agricultural Biotechnology," Brossard, D.; Shanahan, J.; and Nesbitt, T.C. (eds). CABI International: UK.

Accepted Papers and Presentations

Ponce de Leon, I., & Tucker, M. (2010). The role of the Filipino research culture in enhancing science communication and collaboration. *The Annual Meeting of the Society for the Social Studies of Science* (oral presentation). Tokyo, Japan.

Ponce de Leon, I., & Tucker, M. (2010). Faith in the Facts: Local Researchers' Perspectives on Science Communication in the Philippines. *The 30th Annual PAASE Meeting and Symposium* (oral presentation). Madison, Wisconsin, USA.

Ponce de Leon, I., & Tucker, M. (2010). Advancing the land-grant mission through responsible issues management. *The Southern Association of Agricultural Scientists Conference* (oral presentation). Orlando, Florida, USA.

Ponce de Leon, I. , & Morris, P. (2009). The words of many, the language of one: Intercultural Communication. *MANNRS National Conference* (oral presentation) Indianapolis, IN, USA.

Ponce de Leon, I (2008). Infernal Bureaucracy! Using Classical Literature to Teach Classical Theories in Sociology (and Vice-Versa). *Annual Graduate Student Educational Research Symposium* (poster presentation). West Lafayette, IN: Purdue University.

Ponce de Leon, I. & Hedreyda, C. (2007). Presentation: Sequencing and Analysis of Partial Mitochondrial cytochrome b genes of the Visayan Warty Pig (Sus cebifrons). *Annual Research Achievement Awards* (poster presentation). Manila, Philippines.

Ponce de Leon, I. & Hedreyda, C. (2003). Sequencing and Analysis of Complete Mitochondrial 16s rRNA and cytochrome b Genes of the and Philippine Wild Pig (Sus philippensis). *The Philippine Society for Biochemistry and Molecular Biology Annual Research Conference* (oral presentation). Manila, Philippines.

Ponce de Leon, I. & Hedreyda, C. (2003). Sequencing and Analysis of Partial Mitochondrial cytochrome b genes of the Visayan Warty Pig (Sus cebifrons) . *The Philippine Society for Biochemistry and Molecular Biology Annual Research Conference* (pp. poster presentation). Manila, Philippines.

Ponce de Leon, I. & Hedreyda, C. (2003). Sequencing and Analysis of Partial Mitochondrial cytochrome b genes of the Monitor Lizard. *The Philippine Society for Natural Materials Annual Conference* (poster presentation). Baguio City, Philippines.

Ponce de Leon, I. & Hedreyda, C. (2003). Sequencing and Analysis of Complete Mitochondrial 16s rRNA and cytochrome b Genes of the Visayan Warty Pig (Sus cebifrons). *The Philippine Society for Natural Materials Annual Conference* (poster presentation). Baguio City, Philippines.

Ponce de Leon, I. & Miranda, J. (2000). Analysis of DNA in Simulated Forensic Specimens. *The Philippine-American Academy of Science and Engineering Annual Conference* (poster presentation). Manila, Philippines.

Balaoing, F.; Ponce de Leon, I.; & Ponte, M. (1998). Genetic Database in the Philippines. *UNIV National Congress* (oral presentation by Inez Ponce de Leon). Quezon City, Philippines.

Other Productions

Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA). (2008). *Basics of Crop Genetics* [Brochure]. Los Banos Laguna, Philippines: Inez Ponce de Leon.

Ponce de Leon, I. (2005). Bioinformatics. *National Research Council of the Philippines* (oral presentation). Vigan, Ilocos Norte, Philippines: University of Northern Philippines.

Ponce de Leon, I. (2005). Progress in Communication Component for ABSP II SEAsia, Philippine and Indonesian Projects (oral presentation). Los Banos, Philippines: Institute of Plant Breeding.

Ponce de Leon, I. (2005). Progress in Communication Component for ABSP II SEAsia, Philippine Projects (oral presentation). Lembang, Indonesia: Asian Vegetable Research and Development Center (AVRDC).

Ponce de Leon, I. (2002) And What About Biotechnology? Seminar for Medical Representatives (oral presentation). Manila, Philippines.

Mirano, D.; Ponce de Leon, I.; & Que, C.P. (2003). Biotechnology FAQ's (oral presentation). Diliman, Quezon City, Philippines. (December)

Mirano, D.; Ponce de Leon, I.; & Que, C.P. (2003). Biotechnology FAQ's (oral presentation). Diliman, Quezon City, Philippines. (March)

Mirano, D.; Ponce de Leon, I.; & Que, C.P. (2002). Biotechnology FAQ's (oral presentation). Diliman, Quezon City, Philippines: National Institute of Science and Mathematics Education. (November)

Mirano, D.; Ponce de Leon, I.; & Que, C.P. (2002). Biotechnology FAQ's (oral presentation). Tagaytay City, Batangas, Philippines. (May)

Mirano, D.; Ponce de Leon, I.; & Que, C.P. (2002). Biotechnology FAQ's (oral presentation). Cagayan de Oro City, Cagayan de Oro, Philippines. (March)

Mirano, D.; Ponce de Leon, I.; & Que, C.P. (2002). Biotechnology FAQ's (oral presentation). La Trinidad, Benguet, Philippines. (February)

Mirano, D.; Ponce de Leon, I.; & Que, C.P. (2001). Biotechnology FAQ's (oral presentation). La Iloilo City, Iloilo, Philippines. (December)

Mirano, D.; Ponce de Leon, I.; & Que, C.P. (2001). Biotechnology FAQ's (oral presentation). La Diliman, Quezon City, Philippines. (September)

Fiction

Editor-Reviewed Publications and Presentations

Ponce de Leon, I. (2006). <Title of Work Not Disclosed to Author>. *Ani 33, The Literary Journal of the Cultural Center of the Philippines.*

Ponce de Leon, I. (2004). World-dead. *Ani 31, The Literary Journal of the Cultural Center of the Philippines.*

Ponce de Leon, I. (2002). The enlightened. Ani 29, The Literary Journal of the Cultural Center of the Philippines.

Ponce de Leon, I. (2003). A song for the faerie world. *Ani 30, The Literary Journal of the Cultural Center of the Philippines.*

Books/Book Chapters

Ponce de Leon, I. (2004). The Romantic. Atlanta, GA: Lulu Press.

Ponce de Leon, I. (2004). Sanctuary. Atlanta, GA: Lulu Press.

Professional Service and Guest Lectures

Ponce de Leon, I. (2010). Adult Education in the Philippines. YDAE 565 Class, Purdue University (guest lecturer). 5 participants.

Ponce de Leon, I. & Tucker, M.A. (2011). The Words of Many, The Language of One: The Basics of Intercultural Communication. AGR 201 Class, Purdue University (guest lecturer). 100++ participants.

Ponce de Leon, I. & Tucker, M.A. (2010). The Words of Many, The Language of One: The Basics of Intercultural Communication. AGR 201 Class, Purdue University (guest lecturer). 100++ participants.

Ponce de Leon, I. (2010). Cultivating Diversity in Yourself. ANSC 381 Class, Purdue University (guest lecturer). 47 participants.

Ponce de Leon, I. & Tucker, M.A. (2009, Fall). The Words of Many, The Language of One: The Basics of Intercultural Communication. AGR 201 Class, Purdue University (guest lecturer). 100++ participants.

Ponce de Leon, I. (2009). Cultivating Diversity in Yourself. ANSC 495 Class, Purdue University (guest lecturer). 30 participants.

Ponce de Leon, I. & Tucker, M.A. (2009, Spring). The Words of Many, The Language of One: The Basics of Intercultural Communication. AGR 201 Class, Purdue University (guest lecturer). 100++ participants.

Ponce de Leon, I. & Tucker, M.A. (2008). The Words of Many, The Language of One: The Basics of Intercultural Communication. AGR 201 Class, Purdue University (guest lecturer). 100++ participants.

Ponce de Leon, I. (2007). Medical Applications of Molecular Biology. MBB 10 Class, University of the Philippines, Diliman (session speaker). 40 participants.

Ponce de Leon, I. (2007). Biosafety Regulations in the Philippines. Molecular Diagnostic Tools for Viruses and Bacteria: A Hands on Training (session speaker). University of the Philippines, Diliman. 20 participants.

Ponce de Leon, I. (2007). PCR Instrumentation. Molecular Diagnostic Tools for Viruses and Bacteria: A Hands on Training. University of the Philippines, Diliman (session speaker). 20 participants.

Ponce de Leon, I. (2007). Careers in Molecular Biology and Biotechnology. University of the Philippines Integrated Schools (High School) (guest lecturer). 30 participants.

Ponce de Leon, I. (2006) On Forensic Molecular Biology. MBB 10 Class, University of the Philippines, Diliman (guest lecturer). 40 participants.

Ponce de Leon, I. (2006). On Science Communication. Graduating Class Seminar. University of the Philippines, Los Banos. (July) (guest lecturer). 90 participants.

Ponce de Leon, I. (2006). On Science Communication. Graduating Class Seminar. University of the Philippines, Los Banos. (February) (guest lecturer). 80 participants.

Ponce de Leon, I. (2006). Advances in Agricultural Biotechnology. Conference of Philippine Secondary School Teachers. Zamboanga, Philippines (speaker). 300+ participants, high school teachers from all over the Philippines.

Ponce de Leon, I. (2006). Newborn Screening. National Youth Science, Technology, and Environment Summer Camp (PSYSC) (full seminar/symposium speaker). 400++ participants, Elementary School students from all over the Philippines.

Ponce de Leon, I. (2006). Newborn Screening. National Youth Science, Technology, and Environment Summer Camp (PSYSC) (full seminar/symposium speaker). 70++ participants, Elementary School teachers from all over the Philippines.

Ponce de Leon, I. (2005) On Forensic Molecular Biology. MBB 10 Class, University of the Philippines, Diliman (guest lecturer). 40 participants.

Ponce de Leon, I. (2005). On Science Communication. Graduating Class Seminar. University of the Philippines, Los Banos (guest lecturer). (July) 80 participants.

Ponce de Leon, I. (2005). On Science Communication. Graduating Class Seminar. University of the Philippines, Los Banos (guest lecturer). (February) 80 participants.

Ponce de Leon, I. (2005). Science Communication. Meeting of the National Academy of Science and Technology. University of the Philippines, Diliman (speaker). 40 participants.

Ponce de Leon, I. (2004). Advances in Biotechnology. Biology Class, De La Salle University Dasmarinas, Philippines (guest lecturer). 40 participants.

Ponce de Leon, I. (2003). Genetic Engineering and Biotechnology. National Youth Science, Technology, and Environment Summer Camp (PSYSC) (full seminar/symposium speaker). 740 participants, High School students from all over the country.

Ponce de Leon, I. (2003). Advances in Molecular Biology and Biotechnology. Biology Class, De La Salle University, Dasmarinas, Philippines (guest lecturer). 80 participants.

Ponce de Leon, I. (2002). Careers in Molecular Biology. Science and Technology Career Seminar of the Philippine Society of Youth Science Clubs (PSYSC) (speaker). 300++ participants, high school students from all over the Philippines.

Professional Society Memberships

Golden Key International Honors Society (2008)

International Honors Society of Phi Kappa Phi (2000)

Pi Sigma Biological Honors Society (2000)

Other Activities

Graduate School, Ph.D.

Senator and Promotions Committee Head, Purdue Graduate Student Government (2008-2010)

Consulting Team, FEELS program (2008)

Consulting Team, Communication Rubrics for Purdue's College of Agriculture (2007-2008)

Webmaster, Troupe Member, Mirage Bellydancers (2009-present)

Graduate School, Masters

Member, PinoyWriters, group of writers from the Philippines (2001-present)

College

Junior Faculty Adviser, Molecular Biology and Biotechnology Society (2002)

Member, Molecular Biology and Biotechnology Society (1996-2000)

Secondary School

Literary Editor (1994) and Editor in Chief (1995) of the Blue Flame, Official Newspaper

External Affairs officer (1995) of Sigma Mu Epsilon, Official Math Competitors Guild