ABSTRACT

KING, SHERON NICOLE. Exploring Environmental Justice Issues in Emerging Technologies: Public Participation (Under the direction of Dr. Jennifer Kuzma).

As technology develops, modernizes, and globalizes, societal and governance practices associated with emerging technologies must also create, modernize, and globalize. These practices include how to address environmental justice issues that may arise with the emergence of technology. The developing science of environmental justice could be used to promote the maintenance of global environmental injustices or efforts to reduce injustice and increase sustainability. The one-size-fits-all approach to addressing environmental justice issues within different technological developments may not be the best approach as this can exasperate environmental justice issues within a specific community and create new disparaged populations. Although environmental justice has been a subject of discussion in public and academic spheres for several decades, environmental justice as a science, may always be in constant evolution, due to the ever-changing landscape of science and technology.

This research is an exploratory study into how public participation can add to the basis of research for environmental justice issues experienced in the emergence of technology and science. Public participation is linked to environmental justice because it can help ensure that environmental policies are equitable and fair. Rowe & Frewer (2000) state that public participation may help policymakers consider unique perspectives and experiences that they might not have considered otherwise. This all allows for different populations to to be maningfully involved in the development, implementation, and enforcement of environmental laws, regulations, and policies (Moffet, 1996). Effective inclusion can help ensure that all people are treated fairly, regardless of race, color, national origin, or income in the formation of these policies. Public participation can help ensure that decisions are more informed and lead to better

environmental outcomes as well as build trust and promote collaboration between different stakeholders (Rowe & Frewer, 2000).

Environmental justice is based on the idea that, in a democracy, when everyone participates meaningfully in a process whose procedures and substance they understand, no group should be affected unequally by a decision. Public participation is often mandatory in environmental decision-making, such as in environmental impact assessment and urban land use planning. Federal agencies must take steps to ensure that there is adequate and effective communication between decision-makers and affected minority and low-income communities according to some federal executive orders. (Executive Order 12898, 1994).

The first paper explores expert attitudes on the public's participation in technology adoption and governance, focusing on the development of synthetic biology applications. The importance of this research is to examine the expert opinion of synthetic biology applications and the experts' views on the public's role in choices about technology development and governance. Data were collected from the first and second rounds of a more extensive four-round Policy Delphi longitudinal study that included structured interviews, a quantitative survey, a face-to-face workshop, and a final shorter survey, with experts in fields of synthetic biology, its applications as well as related subject matter. A subsample of 11 thematic patterns was taken from this more extensive study, and 53 thematic patterns were taken from the original analysis—pieces of the longitudinal study to accomplish deeper analysis. Thirteen new but connected thematic patterns were identified relating to expert views on public participation in technology development.

The second paper leverages mixed-method content analyses to focus on the comparison of expert opinions by cases and by expert groups that emerge from the original policy Delphi study, PIs Kuzma and Cummings, Looking Forward to Synthetic Biology Governance: Convergent

Research Cases to Promote Policy-Making and Dialogue [#556583]. It also identifies barriers and opportunities, as stated by the experts, towards more public participation in synthetic applications, with varying results depending on cases and expert groups. An identified opportunity from this analysis calls for more developed models of public participation in synthetic biotechnological development. Some of the implications from the study highlighted the how the current and relevant experts recognized the need for enhanced public participation on a variety of levels.

The first and second papers of this exploratory study are important to examine the tension between the public and experts. Examining that tension may assist in identifying where improvements can be made to the systematic policy formations that lead to inequity and inequality for certain populations. This study will gather information to see where experts attitudes towards are for public participation using synthetic biological applications as a catalyst.

The third paper explores a nonprofit's role in increasing its constituents' scientific and technological social capital using genetically engineered food as a vector. Food production continues to utilize emerging technologies to address societal demand. This study adds another dimension to the discussion of public participation in the development and governance of emerging technologies that affect all populations but tend to affect marginalized populations more negatively. The researcher explores how social capital theory can be used by NPOs/NGOs as the world of technology and science changes to create and expand their consumers' social capital. This paper uses a small focus group study to examine several key concepts concerning social capital with regard to genetically modified foods, within several African American churches in the Wake County area of North Carolina. Its purpose is to garner and generate exploratory information to add to the knowledge and possible practices in nonprofit organizational research and the intersectionality of social capital, nonprofit organizations, and environmental justice issues. This focus study found that 89.2% of the participants thought that churches should educate their congregation on food safety and health regarding emerging food technologies, with only 3.1% disagreeing and the remainder unsure. 61.5% of the participants thought churches should advocate for their congregation concerning these technologies. In contrast, a significant percentage of the participants were uncertain about what role the church should play in advocacy, as demonstrated by their uncertainty.

Drawing on insights from the preceding three papers, the final section presents a preliminary research proposal to include diverse communities in a workshop to identify distributive justice issues associated with transgenic pests. This proposal postulates examining public input on the final decisions of the governance of agricultural transgenic pests in the American government within the realm of distributive justice.

Exploring Environmental Justice Issues in Emerging Technologies:
Public Participation

by

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BIOGRAPHY

Sheron N. King is a Ph.D. student in the Public Administration Department at North Carolina State University. She was selected to be a graduate assistant in the Genetic Engineering and Society department on a policy Delphi study on governance of synthetic biology and its effect on society funded by the Alfred P. Sloan Foundation; as a Co-Investigator on the Cultural Attitudes towards Genetically Engineered Foods Study funded by the Genetic Engineering and Society Center; and performed as a Co-Principal Investigator in the Early Inclusion of Environmental Justice Communities in Governance of Emerging Technology Workshop funded by Alfred P. Sloan Foundation and the Genetic Engineering and Society Center.

She has presented at 2014 American Society of Public Administrators (ASPA) as a Founder’s Fellow on theory to practice initiatives; presented at the 2014 annual conference for the Conference of Minority Public Administrators (COMPA) on how social capital of underrepresented communities can be affected by non-profit organizations that serve them; co-presented at the Governance in Emerging Technology (GET) annual conference held in Scottsdale, Arizona; presented research posters at the Workshop on Research Agendas in the Societal Aspects of Synthetic Biology in Tempe, Arizona; the Democratizing Technologies: Assessing the Roles of NGOs in Shaping Technological Futures in Santa Barbara, California; and the North Carolina State University Graduate Research Symposium. She was also selected as a fellow in the Integrative Graduate Education and Research Traineeship funded by the National Science Foundation in 2014 and presented a working research paper entitled *When Expert Opinion Meets the Public: What the Experts Are Really Saying*, at the Governing Emerging Technology Conference in May of 2015.

Her research interest include science and technology, non-profit organizations, and theory to practice initiatives. Her professional background includes experience in counseling, non-profit administration, child welfare, and education. She has a Master’s of Science in Education (MS.Ed) in Community Counseling from Old Dominion University as well as a Bachelor’s of Science (BS) in Marine and Environmental Science & Leadership Studies from Hampton University.

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Dissertation Introduction

Exploring environmental justice as it relates to emerging technologies can seem like a daunting task. Each technology has its definitions, societal effects, negative externalities, and benefits. Some emerging technologies disparage distinct populations, while other emerging technologies directly benefit those same distinct populations. ***Emerging technologies*** can be defined as "new technologies that are currently developing or will be developed over the next five to ten years, and which will substantially alter the business and social environment" (Rotolo, Hicks, & Martin, 2015, P. 2). Another way to define emerging technologies is technologies that are perceived as capable of changing the status quo. "These technologies are generally new but include older technologies that are still controversial and relatively undeveloped in potential" (Rotolo, Hicks, & Martin, 2015, P. 2). Some examples of these technologies include but are not limited to gene therapy and genetically engineered organisms and food. Emerging technologies can also be defined as:

> "…a radically novel and relatively fast-growing technology characterized by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socio-economic domain(s) which is observed in terms of the composition of actors, institutions, and patterns of interactions among those, along with the associated knowledge production processes. Its most prominent impact, however, lies in the future, so the emergence phase is still somewhat uncertain and ambiguous" (Rotolo et al., 2015, p. 4).

Emerging technologies include "educational technology, information technology, nanotechnology, biotechnology, cognitive science, psychotechnology, robotics, and artificial intelligence." (Rotolo et al., 2015, p. 6). Some technology emerges because of a symbiotic marriage between two seemingly unrelated fields. Byron Kaldis stated in his 2010 book Converging Technologies that new technological fields and advancements may result from the technological convergence of different systems evolving towards similar goals. Kaldis goes on to state that convergence uses older, separate technologies such as data (including productivity applications), voice (and telephony features), and video together. These older technologies are then able to share resources and interact with each other in ways that create new ways of experiencing those technologies (Kaldis, 2010). Emerging technologies can be characterized by prominent environmental and social impact, coherence with the status quo and other technologies, uncertainty and ambiguity, radical novelty, and relatively fast developmental and economic growth. Converging technologies consist of distinct fields of technological applications that are moving toward synergy with one another (Kaldis, 2010) as compared to emerging technologies in which technological innovations are created to expand the field of knowledge and practical application (Kaldis, 2010).

Just as emerging technologies lend themselves to a specific definition within the scope of a particular discussion and response to external stimuli, *environmental justice* has responded similarly to external conditions related to emerging technological processes that may adversely affect specific demographics. Environmental justice can be described as a response to environmental conditions, political and systematic policies, and institutionalized practices that those affected have judged to be illegal, unfair, or unjust in some way (Bullard & Johnson, 2000). A growing body of evidence suggests that communities adversely affected are likely to be poor, people of color, indigenous peoples, minorities, and citizens of developing countries or women (Bullard & Johnson, 2000; Institute of Medicine, 1999; Johnson, Williams, & Harris 1992; National Institute for Environmental Health Sciences, 1995). Bullard and Johnson (2000) list some of these practices, policies, and conditions, including “1) unequal enforcement of environmental, civil rights, and public health laws; 2) differential exposure of some populations to harmful chemicals, pesticides, and other toxins in the home, school, neighborhood, and workplace; 3) faulty assumptions in calculating, assessing, and managing risks; 4) discriminatory zoning and land-use practices, and 5) exclusionary practices that prevent some individuals and groups from participation in decision making or limit the extent of their participation” (Bullard & Johnson, 2000, p. 557; Bullard, 1993; Lee, 1992). Environmental justice also concerns whether members of these groups have fair access to environmental goods such as urban green spaces, forested areas, clean water, and technology. Environmental goods also extend opportunities to benefit from enterprises such as tourism and green infrastructure built from emerging technologies (Shrader-Frechette, 2002; Bullard, 2000; Taylor, 2000; Whyte, 2010).

These practices or conditions are an externality, either positive or negative, of the development and distribution of emerging technologies. In response to these externalities, environmental justice lends itself to preventing these disproportionate externalities through various activities. Bullard and Johnson (2000, P. 559) state that

> “The environmental justice framework adopts a public health prevention model (i.e., elimination of the threat before harm occurs) as the preferred strategy. The environmental justice framework shifts the burden of proof to polluters/dischargers who harm, discriminate, or do not give equal protection to people of color, low-income persons, and other “protected” classes. The environmental justice framework allows disparate impact and statistical weight or an “effect” test instead of “intent” to infer discrimination. The environmental justice framework redresses disproportionate impact through “targeted” action and resources. This strategy would generally target resources where environmental

and health problems are greatest (as determined by some ranking scheme but not limited to risk assessment)."

Much ethical debate centers on issues of distributive justice in allocating access to beneficial forms of technology. Some thinkers, such as environmental ethicist Bill McKibben, oppose the continuing development of advanced technology partly out of fear that its benefits will be distributed unequally in ways that could worsen the plight of people experiencing poverty (McKibben, 2003). The dominant environmental protection paradigm "institutionalizes unequal enforcement; trades human health for profit; places the burden of proof on the "victims" and not the polluting industry or the developers of the technology; legitimates human exposure to harmful chemicals, pesticides, and hazardous chemicals; promotes "risky" technologies; exploits the vulnerability of economically and politically disenfranchised communities; subsidizes ecological destructions; creates an industry around risk assessment and risk management; delays cleanup action; and fails to develop pollution prevention as the overarching and dominant strategy" (Bullard & Johnson, 2000, P. 557; Austin & Schill, 1991; Bullard, 1992, 1993b.). Contrastingly, inventor Ray Kurzweil is among the experts who believe that emerging and converging technologies could and will eliminate poverty and abolish suffering (Kurzweil, 2005).

Emerging technologies and environmental justice are ultimately related because one impacts the other. It is almost impossible to develop new technology that changes the societal landscape of the global community and does not have intended and unintended negative externalities, as well as an imbalance in the distribution of positive externalities. A development model where experts and regulators think about these externalities upfront and work fluidly and actively to manage them aligns with the call for environmental justice research. This is important as Bill Joy highlighted when he warned that “the experiences of the [Manhattan Project] clearly show the need to take personal responsibility, the danger that things will move too fast, and [how] a process can take on a life of its own. As they did, we can create insurmountable problems in almost no time flat. We must do more thinking up front if we are not to be similarly surprised and shocked by the consequences of our inventions” (Joy, 2000, P. 15-16). Some writings, including that of computer expert Bill Joy, have identified “clusters of technologies that they consider critical to humanity's future,” used by elites for good or evil. These elites could use it as "good shepherds" for the rest of humanity, or decide everyone else is “superfluous and push for the mass extinction of those made unnecessary by technology” (Joy, 2000, P. 4).

Advocates of the benefits of technological change typically see emerging and converging technologies as offering hope for the betterment of the human condition. Cyberphilosophers Alexander Bard and Jan Söderqvist argue in *The Futurica Trilogy* that relevant change is a result of technological innovation, either directly or indirectly, while, in contrast, humanity is constant throughout human history because genetic changes take a very long time (Bard & Soderqvist, 2012). Therefore, society should be regarded as history's main constant and technology as its primary variable. However, critics of the risks of technological change, and even some advocates such as transhumanist philosopher Nick Bostrom, warn that some of these technologies could pose dangers, perhaps even contribute to the extinction of humanity itself, i.e., some of them could involve existential risks (Bostrom, 2002).

Some analysts, such as Martin Ford (2009), argue that as “information technology advances, robots and other forms of automation will ultimately result in significant unemployment as machines and software begin to match and exceed the capability of workers to perform most routine jobs. As robotics and artificial intelligence develop further, even many skilled jobs may be threatened, which, in turn, creates environmental justice issues" (Ford, 2009, p. 117). Technologies such as machine learning may facilitate computers to do many knowledge-based jobs that require significant education. Ford states that this may "result in substantial unemployment at all skill levels, stagnant or falling wages for most workers, and increased concentration of income and wealth as the owners of capital capture an ever-larger fraction of the economy" (Ford, 2009, p. 120). This could lead to depressed consumer spending and economic growth as the bulk of the population lacks sufficient discretionary income to purchase the products and services produced by the economy (Saenz, 2009; Ford, 2011).

As technology develops, modernizes, and globalizes, societal definitions and practices associated with emerging technologies must also develop, modernize, and globalize. These include how to address environmental justice issues that may arise with the emergence of technology. The one-size-fits-all approach to addressing environmental justice issues within different technological developments may not be the best approach as this can exasperate environmental justice issues within a specific community and create new disparaged populations. The current state of the environmental justice paradigm calls for the involvement of advocacy communities to organize around technology that adversely affects a population or specific community. Steve Wing, a founding member of the North Carolina Environmental Justice Network, calls for research to create a foundation for "the science of environmental justice." The science of environmental justice "can serve as a knowledge base for public…advocacy" (Wing, 2005, pp. 55-56). The developing science of environmental justice could be used to accommodate the production and maintenance of global environmental injustices, or it could be used to promote efforts to reduce injustice and promote sustainability.

Although much has been written on the environmental justice movement, attention has generally been "focused on case studies, analyzing the spatial distribution of environmental hazards, and examining policy formulation" (Taylor, 2000, p. 508). Policy analysis may benefit from a methodology that acknowledges that "scientific knowledge is dependent upon the normative assumptions and social meanings of the world it explores" (Robyn, 2002, p. 212). Dorceta Taylor (2000, P. 509) suggests that environmental justice issues are constructs of social problems, meaning "environmental problems are not static." Therefore, environmental justice issues related to developing technology follow the exact definition. Environmental justice issues change according to how science and technology change. The advancement of scientific and technological applications directly affects how environmental justice issues should be addressed. Taylor explains that "groups in a society perceive, identify, and define environmental problems by developing shared meaning and interpretations of the issues" (Taylor, 2000, p. 509).

In this dissertation, the research attempts to flush out specific environmental justice issues as they relate to three different emerging technologies, namely, 1) four specific applications of synthetic biology, 2) genetically engineered food, and 3) agricultural transgenic pests, namely, the Citrus tristeza virus vectored by aphids. The first and second paper explores expert attitudes on the public's participation in technology adoption and governance, focusing on the development of synthetic biology applications. The importance of this research is to examine the expert opinion of synthetic biology applications and the experts' views on the public's role in choices about technology development and governance. C.S. King et al, (2015) highlighted that the traditional view of public participation attempts to create solutions for an issue, experienced by all citizens, by asking the opinion of those citizens last, often referred to as the deficit model. The solution is first examined through administrative systems and processes, then administrators who make the final decision, and then seeks the opinion of the public. The alternative model for public participation places the citizen next to the issue (such as an environmental justice issue), seeks out and facilitates their participation, relies less on government as the expert and more on government as a convener and the final decision maker, and sees administrative systems and processes as a set of tools that should be used to facilitate engagement rather than channel and limit engagement.

The third paper explores a nonprofit's role in increasing its constituents' scientific and technological social capital with genetically engineered food. Food production continues to utilize emerging technologies to address societal demand. It adds another dimension to the discussion of public participation in developing and governance of emerging technologies that affect all populations but tend to negatively affect marginalized populations more. The final paper is in the form of a preliminary research proposal that proposes how to engage publics in the regulatory space through a workshop and, eventually, an analysis of public comments to identify distributive justice issues.

Environmental Justice: The Dualism of Practical Application and Theoretical Foundation

This research project aims to explore these environmental justice issues in the context of each case study to embed consideration of environmental justice into technology governance practices upstream of scientific and technological development. The research and practices (and resulting cycle) that may help to eliminate, alleviate, address, and solve the environmental justice issues that can be, have been, and will be experienced due to technological and scientific developments over various fields and applications. It is of the utmost importance to recognize the need to use practical knowledge to inform theoretical knowledge, which can then inform practical knowledge.

Exploring environmental justice issues within the scope of emerging technologies falls under public administration theory and practice. The concept of theory to practice within public administration has been controversial and discussed for several decades. The reason for this is straightforward. Jamil Jreisat (1978) stated that “in most aspects of public administration, the conceptual and the practical are intertwined” (pg. 504). He postulated that focusing on one without the other would create dissatisfaction within the student body of public administration and an unprepared “professionally trained public personnel” (pg. 509). Mark Evans (2007) asks society if academic knowledge should be used in practical applications more efficiently, and if so, how? (pg. 128).

Although public administration’s search for an identity as a field has reached a contemporary debate supported by decades of work, it seems plausible that there *still* would be some difficulties in bridging research, theory, and practice at such intersections of emerging technology and environmental justice. This difficulty may result from the dualities that may always live within the profession. Public administration scholars continue to debate whether it is a science or an art or some complicated relationship between the two. Lynn (1994) stated that “if communicable clarity and understanding are the goals…art and science must both be crafted into balance” (pg. 254). Donna Shalala (1977) also spoke of these dualisms. She stated that the “field was riddled with dualisms: politics versus administration, fact versus value, and academic versus practitioner” (pg. 570). Behn (1995) states that “the clear division of labor between politics and administration…is…completely unconnected to reality” (pg. 317). Lynn (1993) describes how “public managers are both principals and agents” (pg. 13). Legislation or policy is made for others that also have to be adhered to by the makers. Procedural rules are created for public agencies that prevent the agency's achievements, for which public managers are responsible

(Behn, 1995). It is logical to assume that public administration's theoretical bases, research methods, and practical applications would be diverse and, sometimes, opposites. This duality is visible within the field of emerging technologies and the environmental justice issues that surround those technologies.

Addressing these dualities begins with asking how to align theory to practice. This process starts with the development of public administration theory. Perry (1991) discusses a possible strategy for developing and improving upon public administration theory, the utilization of middle-range theory. I argue that middle range theory may be one of the best ways to add to public administration’s knowledge and practical application, especially in the case of environmental justice. I believe this strategy creates a much-needed balance by considering the need for both empirical and scientific study as well as the importance of practical application to real-life situations. This theory building strategy could be used in bridging “practical inquiry-focused on the immediate, relevant, common-sense world – and the theoretical inquiry” (Perry, 1991, P. 5). Many practitioners have yearned for academic theories that could be translated into actual solutions relevant for the populations being served including populations affected by environmental justice issues.

Perry (1991) discusses how Merton’s concept of middle-range theory can help to explain the relationship between “interconnected sets of propositions midway between unified theory that explains all uniformities and minor, working hypotheses” (pg. 6). Certain characteristics of middle-range theory may better embody the nature of the relationship between public administration theory and public management practice. For instance, middle-range theory states analytical concepts can be more abstract than empirical generalizations found in other cognate fields of study (Perry 1991). Another characteristic is that middle-range theory are usually derived from data rather than grand theories (Perry 1991). Often, in practical application, issues and solutions can be identified from the data that is currently available or specific phenomena actively affecting the society (i.e. from the work in this dissertation on expert attitudes towards public participation in the development of synthetic biology; nonprofit involvement with the development of genetically engineered food for their constituents; and the influence of public comments in regulatory decisions concerning the release of an agricultural transgenic pest).

Craig Christiansen (2012) speaks to changing how academics use language in their papers. He discusses how academics could revamp who is included in their audience by changing their use of language and as a result, attract practitioners as a reading base. He suggested that theorists try to remember that those who are not theoreticians will benefit from being given definitions of conceptual constructs. He states that even those practitioners who dismiss theory as irrelevant, are indicating that they want "theory that is applicable to their daily practice" (pg. 479). He suggests that by using strategies such as explaining the plausibility of the theory and its practical application, we could improve practitioners' exposure to relevant conclusions for daily practice generated from theory.

The next step is conducting research that is conducive to theory-to-practice initiatives. Some of these research techniques include problem-solving-oriented research, action research designs, and empirical analysis of practice. Empirical studies such as Williamson and Snow (2013) used descriptive statistics and correlations to examine and determine the extent to which practices within local school districts were consistent with public management reform theories (pg. 162). Their study identified "major gaps between theory and practice for practitioners and researchers to study" (pg. 171).

Exploring environmental justice issues in emerging technologies could benefit from opening itself to unconventional, experimental research designs if subject-matter experts and academic researchers want to understand how to turn current theory into practical application. Riccucci emphasizes compromise over using different research methods to obtain knowledge within our ever-changing, “more than multi-disciplinary” field (Riccucci, 2010; Newland, 1994). She argues that public management and/or public administration issues [including the exploration of environmental justice issues in emerging technologies] do not lend themselves to empirical study and that “knowledge is derived from impressions both on intellect and on the senses” (pg. 174). Arthur Sementelli (2009) suggested using “popular media to bridge theories and practices” by presenting an approach for using “film and video to integrate contemporary social theory into management instruction and inquiry” (pg. 607). He argued that these strategies were contextual and required commitment from practitioners and professors. This commitment was identified as a desire to stay relevant and current and increase our awareness of the “shifts of how meaning is conveyed” (pg. 617).

Perry, J. L. (1991) stated in his paper, Strategies for Building Public Administration Theory, that public administration “has grown so broad and so involved with activities at its periphery” and that it has become “diverse and complex” (pg. 6). The diversity and complexity of public administration and management lie within the fact that it contends with the human condition constantly, in theory, and practical application. New phenomena emerge as “market-like mechanisms, hierarchical arrangements, and social relationships” (Lynn, 1993, p. 14) change over time.

Unlike grand theories, middle-range theories target a particular issue within public administration, such as public participation, allowing for more detailed analysis. By focusing on practical issues, middle range theories can directly inform policy decisions and organizational practices within the public sector (Perry, 1991). By focusing on specific areas, researchers can build upon existing knowledge and develop a more comprehensive understanding of complex public administration such as public participation in the intersections of emerging technology and environmental justice. One of the aims of this study is to examine the implications for practitioners and academics that strive to build a bridge between theory building, research designs, and practical application to shoulder the needs of a diverse society, by adding knowledge to a middle-range theory (Perry, 1991) between public participation, emerging technology and environmental justice.

Dissertation Research Questions

As synthetic biology applications become a more significant part of the emerging technology discussion, questions that focus on a particular issue arise such as:

- What do experts know and think about the public involvement in developing synthetic biology applications and, more importantly, the public's role in developing the public policy that governs emerging technologies?
- What do experts believe the role of the public should be in developing synthetic biology applications?
- What do experts believe the role of the public should be in developing public policy regarding synthetic biology?
- What are the patterns between expert groups and between case study applications?
- What are the misconceptions (i.e. lack of knowledge) the experts have about the public?
- What do experts believe the role of the public should be in developing public policy regarding synthetic biology?

- By default, how do experts envision technology concerning society at large?

The scope of the research in Paper 1 will attempt to explore these questions:

- What do experts believe the role of the public should be in developing synthetic biology applications?
- What patterns emerge in expert opinion in developing synthetic biological applications?
- What opportunities and barriers are identified by experts to institutionalizing the public's role in synthetic biological R&D and policy meaningfully?

These three questions will be explored in the 2nd paper of this study:

- Do expert groups differ by affiliation in their beliefs about the role of the public with regard to synthetic biology?
- What are the differences in expert discussion on public attitudes with regard to synthetic biology applications?
- Do experts believe that the role of the public should differ based on the synthetic biology of the application being developed?

These three questions will be explored in the Paper 3 of this study:

- If the participants thought that churches should educate their congregation on food safety and health of emerging food technologies (human capital 1).
- If churches should advocate for their congregation concerning food technologies (network capital).
- If religious entities are obligated to educate their congregation members regarding food technologies (human2/network).
- If they trusted their pastor the most to tell the congregation members the truth about genetically modified food.

The following research questions could be explored in the Proposal analysis:

- How do the environmental impact statement and pest risk assessment address the concerns of the comments made by the public in this forum?
- Do people who participate in the Notice Public Comment sections care about environmental justice concepts?
- How does the agency address the comments about environmental justice?
- How could the APHIS-USDA plan to consider legitimate claims to safety concerns with the approval or disapproval of this release, if any?

These questions probe expert opinions on the role and value of public participation in synthetic biology research and development.

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Paper 1: When Expert Opinion Meets the Public, Part 1:

What Are the Experts Saying About Public Participation?

Thematic Analysis of Synthetic Biology

ABSTRACT

This research paper investigates how scientific experts who are vested in developing synthetic biology applications view the role of the public and public engagement in the research and development processes.

Following a Policy Delphi protocol, this paper first explores experts' attitudes and opinions on the role of the public concerning the development and use of four specific synthetic biology applications currently being researched and developed: biomining, cyberplasm, de-extinction, and plant microbes for nitrogen-fixation. Data were collected from the first and second rounds of a more extensive four-round Policy Delphi longitudinal study that included structured interviews with synthetic biology experts, a quantitative survey, a face-to-face workshop, and a final shorter survey. Delphi studies like this one provide iterative processes that calibrate and reveal opinions through multiple rounds of data collection. This paper uses crosstab analysis to focus on the interpretation of thematic patterns that emerge from the first rounds of the Policy Delphi study and what these thematic patterns imply about the attitudes of experts and policymakers towards the public's participation in the research and development of synthetic biology applications.

The 13 thematic patterns identified in the coding of the expert interviews included paper one: *information sharing, transparency, apparency, education, outreach, knowledge, equity, social contracts of experts, control of technology, acceptance, comparisons to other countries, similarities to genetically modified foods, and economics.*

It also identifies barriers and opportunities, as stated by the experts, towards more public participation in the synthetic applications, with varying results depending on the expert group and cases.

Introduction (The Deficit Model)

Expert attitudes towards the public's roles in science and technology, explicitly emerging technology, may affect the scope of current and emerging environmental justice issues within science and technology development. Traditionally, scientific and technological policy is created and developed without the general public's input, a situation known as the deficit model. Grant (2023, pg. 1) simply states, "the model assumes that nonscientific audiences are in some senses empty vessels suffering from a deficit of scientific knowledge, waiting to be filled with the wisdom of science." The deficit model negatively impacts the desire of experts to include the opinion of various publics in scientific and technological research, development, and policy due to the perception that the public lacks the knowledge (both technical and social) to weigh in on such decisions. Other scholars have embarked on the question confronting the governance of science: "how to bring knowledgeable publics into the front-end of scientific and technological production – a place from which they have historically been strictly excluded" (Jasonoff, 2011, p. 235). This ideology begins with the attitude of the experts, experts, and policymakers themselves. Suppose experts, experts, and policymakers acknowledge the importance of public participation in technological and scientific advances. In that case, the scope of environmental justice issues considered is likely to change and how environmental justice issues are to be addressed. As the public will be impacted by expert opinion, the relationship between experts' opinions and the public's role is vital in addressing environmental justice issues. It can serve as a springboard in shaping perceptions of the public's role as new technology emerges. Without constant reevaluation of the current models of decision-making, new and specific populations that may not have been considered before the emergence of the new technology may become disenfranchised.

As a corollary, this discussion has broad implications for understanding the outcomes and consequences associated with technologies as they emerge for different populations. This discussion also lays the necessary groundwork as a paradigm for deciphering what is just and unjust for those populations, especially those disproportionately affected by environmental justice issues stemming from emerging technology. By examining these attitudes from experts from different stakeholder groups, we can understand how to develop and incorporate models of public engagement that create, sustain, and eventually provide a meaningful public stake in emerging technology research and development, therefore addressing and minimizing potential environmental justice issues that could arise or deepen concerning emerging technology and its applications.

This research examines what it means for the public to be involved in the decision-making stages of emerging science and technology from the expert point of view. This relationship is vital in addressing environmental justice issues, who has what portion of the outcomes and consequences of those technologies, therefore deciding what is just and unjust, what is fair and unfair for different populations, especially those disproportionately affected by environmental justice issues stemming from emerging technology. Old public engagement models in emerging technology development may create negative externalities for new populations, creating environmental injustices for those populations. To combat this, old models must continuously be evaluated to minimize these environmental justice issues and negative externalities. Data to evaluate current models can be gathered by examining the current expert and policymaker attitudes toward public participation in developing emerging technologies and their applications.

As new technology and its research emerge and develop, public participation in research and development has also evolved. The populations affected by these evitable changes create new voids in the negative and positive externalities that manifest as environmental justices and injustices. Environmental justice is defined as advocacy that has emerged in response to practices, policies, and conditions that residents have judged to be unfair, unjust, and illegal concerning emerging technology. These practices, policies, and conditions unevenly affect the said population, intentionally or unintentionally, in the developmental research or distribution of a specific technology. Each technological application is different, and therefore, each externality (both positive and negative) is different. Such differences can affect or create populations disadvantaged by those externalities while uplifting others. For example, cases of synthetic biology whose main applications could be within the medical field, a field that already unevenly affects specific populations around the world, is currently deeply embedded in a capitalistic business structure and, therefore is based on price points and access is granted to those who can afford it. Environmental justice issues arise when those who may need technology to save their life either have to forgo treatment due to financial constraints or accept treatment at the detriment of future endeavors that may require financial support (cannot attend college because of the lack of money due to payment towards the treatment of illness). These external conditions create negative externalities or environmental injustices because this technology is based on a system in which access is based on who has the means to procure it. Increasing public participation in science and technological development and research may illuminate and minimize the environmental justice issues that new populations may experience as new technologies replace obsolete ones. It may also build upon other models of public engagement, allowing them to become more fluid in terms of applying to specific populations as well as specific technological and scientific advances. The ‘one size fits all’ models of public engagement developed in the past (Rowe & Frewer, 2000; Jasonoff, 2011) may not be productive in the future when engaging the public in actual decision-making processes.

This research explores experts' attitudes toward public participation using case studies of synthetic biology applications in various stages of research and development. The literature and the research questions form the basis for several hypotheses about predicting the relationship between expert opinion and their views on public engagement. Emerging scientific and technological applications may present new environmental justice issues or exacerbate existing ones, so examining each new case, such as is presented in this research, may be a prudent approach. The scope of this research will attempt to focus on these questions:

1. What do experts believe the role of the public should be in developing synthetic biology applications?
2. What patterns emerge in expert opinion in developing synthetic biological applications?
3. What opportunities and barriers are identified by experts to institutionalizing the public’s role in synthetic biological R&D and policy meaningfully?

As social experts have noted, public perceptions of science affect how the public engages “in decision-making processes that shape the direction of science and technology” (Freudenburg & Pastor, 1992; Miller, 1983; Bak, 2001, p. 779). Examples of public influence on the direction of emerging technologies can be seen in recent current events. In the last 20 years, debates regarding foods containing genetically modified or nano-engineered ingredients have often related to public opinion. Pew Research Center conducted a study between October 2019 and March 2020 in which 48% of the subjects in 20 global publics stated that they think genetically modified foods are unsafe. In the study, Russia (70%), Italy (62%), India (58%) and South Korea

(57%) view GM foods as generally unsafe to eat. Even in places where large parts of the population proclaim that they are not educated enough to make an informed opinion, the opinion towards GM foods can be adverse. For example, the Pew Research Center study found that 47% of Spaniards said GM foods are unsafe, while 13% stated they are safe to eat. Australia was the only place surveyed where equal amounts of the population disagreed on whether GM foods were safe or unsafe (31% to 31%).

On the other hand, scientific consensus seems to converge on the 'safe side' of GM foods, although many of the publics surveyed have expressed some worry about possible health implications from these new practices. A 2016 report from the National Academies of Science, Engineering, and Medicine highlighted a consensus among scientific experts in the United States that there was "no substantiated evidence of a difference in risks to human health between current commercially available genetically engineered (GE) crops and conventionally bred crops". In 2019, an expert panel in Japan's Ministry of Health, Labour, and Welfare came to the same conclusion.

Studies on expert attitudes toward the public have substantial implications for models of public engagement and participation in public policy on science and technology. Phillips and Orsini (2002) attempt to highlight the concept of "[public] impact" in their definition, which is modified and derived from Barney 2006. They describe public engagement as "interactive and iterative processes of deliberation among citizens and between citizens and government officials to contribute meaningfully to specific public policy decisions in a transparent and accountable way" (Powell & Colin, 2008, p. 128). Many policy practitioners and academics have constructed and assessed public participation forums and models. As technology emerges, those models may need to adapt, incorporating specific obstacles associated with the new technology.

Creating opportunities to structure and restructure public engagement models as technology emerges could identify new barriers and/or opportunities towards institutionalizing the public's roles in science and technology research and development and, therefore, anticipate, minimize, and/or eliminate environmental justice issues. Further, by continuing to learn how to adapt efforts to institutionalize the public's role in a meaningful way in real-time, experts begin to accept responsibility and act responsibly as innovation moves forward. Experts and policymakers can examine their influence on global perspectives concerning the public's role in science and technology research and development AND the outcomes of that influence, including the scope of creating and sustaining disadvantaged communities affected by injustices created by emerging technology.

Methodology

The work reported here is situated within a larger project funded by the Alfred P. Sloan Foundation (PIs Kuzma and Cummings, Looking Forward to Synthetic Biology Governance: Convergent Research Cases to Promote Policy-Making and Dialogue [#556583]). The team employed a multi-stage policy Delphi method to facilitate data and information collection using a multidisciplinary expert panel. This Delphi method is a powerful source of grounded theory in that "it is inductively generated from fieldwork" (Palinkas, Horwitz, Green, Wisdom, Duan, & Hoagwood, 2015, pg. 234; Patton, 2002, pg. 40). Grounded theory "emerges from the researchers' observations and interviews in the real world rather than in a laboratory…" (Patton, 2002, pg. 40). Methods of future studies and policy sciences were used to develop and examine synthetic biology (SB) cases in the context of risk policy and governance (Bell, 2004; Bevir, 2009). In particular, Upstream Oversight Assessment was used to help select cases, develop initial drafts of the case studies, and construct questions to inform risk analysis and oversight policy (Kuzma, Romanchek, Kokotovich 2008). The policy-Delphi process (Turoff, 1970) was used to refine the case studies and elicit expert-stakeholder opinions (SMEs) about the potential risks, benefits, and ethical, legal, and societal (ELSI) issues associated with synthetic biological cases. The Delphi consisted of four rounds: a semi-structured interview, a quantitative survey, a face-to-face workshop, and a final shorter survey (Ndoh, C., Cummings, C.L., Kuzma, J., 2020). The data used in this paper is primarily from the first round of interviews of the longitudinal Delphi process. The research focuses on thematic patterns found in specific sections of the initially coded interviews that relate in some way to public engagement and are analyzed for each case and expert grouping (Cummings & Kuzma, 2017).

Case study selection

First, the team identified and selected ten diverse case studies of emerging synthetic biological applications by reviewing widespread media reports on synthetic biology research, cases from other policy conversations, and the peer-reviewed and gray literature. Ten potential case studies were developed (A 2-page case study was vetted for accuracy by a set of synthetic biological experts who were not participants in this study). These synthetic biologists and policy scholars reviewed and commented about those that would best 1) cover a range of environmental release applications, 2) represent a range of synthetic biological technologies from highly engineered organisms to completely synthetic machines, and 3) show plausible cases that were being researched in labs at early or mid-stages or in other words, if successful would be deployed in 10 to 50 years. The resulting final four case studies throughout the policy Delphi project were utilized: biomining using highly engineered microbes in situ, cyberplasm for environmental detection, de-extinction of the passenger pigeon, and engineered plant microbes to fix nitrogen on non-legumes (Cummings & Kuzma, 2017).

A case study analysis approach guided by upstream oversight assessment and anticipatory governance was used to guide question formulation for the interview and survey protocols that would be used to analyze risk analysis and oversight policy issues (Kuzma et al., 2008; Yin, 2002). Kuzma et al. (2008, Pg. 1081) stated that the goal of upstream oversight assessment is to "identify data, risk assessment, regulatory policy, and engagement needs for overseeing these products so they can be addressed prior to market entry… has potential as a key element of anticipatory governance". This study uses distinct case studies of proposed and "in research and development" applications of synthetic biology to highlight areas that can be utilized to develop a model of public participation. This method was called for in the upstream oversight assessment. (See Appendix B: Synopsis of Case Studies)

The expert sample

The sampling of experts was done purposively to attain information on risk, governance, and policy issues of synthetic biology applications. These sampled experts represent "information-rich" cases (Palinkas, et. al., 2015, pg. 234; Patton, 2002, pg. 40) to provide insight into the emerging ethical and social aspects manifested by the governance of the next generation of applications in synthetic biology. It was essential to draw from various expertise areas to cover multiple considerations for public engagement views and acknowledge the values and assumptions in risk analysis. The sampling of experts aimed to get similar numbers of representatives from different types of organizational affiliations and disciplinary perspectives.

The expert-stakeholder list was compiled using a mixture of web database searches and literature reviews for pertinent author names. Using basic Google database search techniques, the project team found several resources that yielded the names of experts and analysts associated with synthetic biology. Upon reading material associated with synthetic biology (peer-reviewed journal papers, synthetic biology conference speaker lists, industry websites, etc.), the project team could categorize the expert stakeholders into six units according to the originating information. The initial set of experts contained 234 persons originating from the following groups: editorial review boards for key journals like *Biotech and Bioeng,* Gordon Research Conference on Synthetic Biology speakers, BioBricks Foundation Synthetic Biological 6.0 meeting, SynBioBeta Conference speaker list (n=7), Georgia Tech Frontiers in Systems and Synthetic Biology conference list, National Science Foundation and Department of Energy synthetic biology policy workshop lists, President's Commission on the Ethics of Synthetic Biology, and other sources (e.g. recommendations made directly to project staff).

The project team recruited the stakeholders to gain expertise and affiliation. Affiliations included academe, industry, government, non-governmental organizations, and others (e.g., think tanks). The subject matter expert (SME) group used in the orginal study, according to self-reported disciplinary perspectives, was comprised of chemists, molecular biologists, engineers, sociologists, toxicologists, environmental experts, lawyers, Science, Technology, and Society (STS) scholars, philosophers, and policy practitioners or scholars, and others. Four primary groups of experts by discipline were formed for analysis based on similar methods of inquiry: 1) Biochemical/Molecular Biology/Chemistry, 2) STS/Sociology/Philosophy/Ethics, 3) Ecology/Environmental Science/Toxicology, and 4) Policy/Law. Some experts identified with more than one disciplinary group (Figure 1). Results for the expert group of ecology, environmental science, and toxicology have been scaled to account for the disproportionate amount of experts in that disciplinary group as compared to the other three groups (all other expert groups had 2.3 times more expert participants than the group whose participants identified in the disciplines of ecology, environmental science, toxicology).

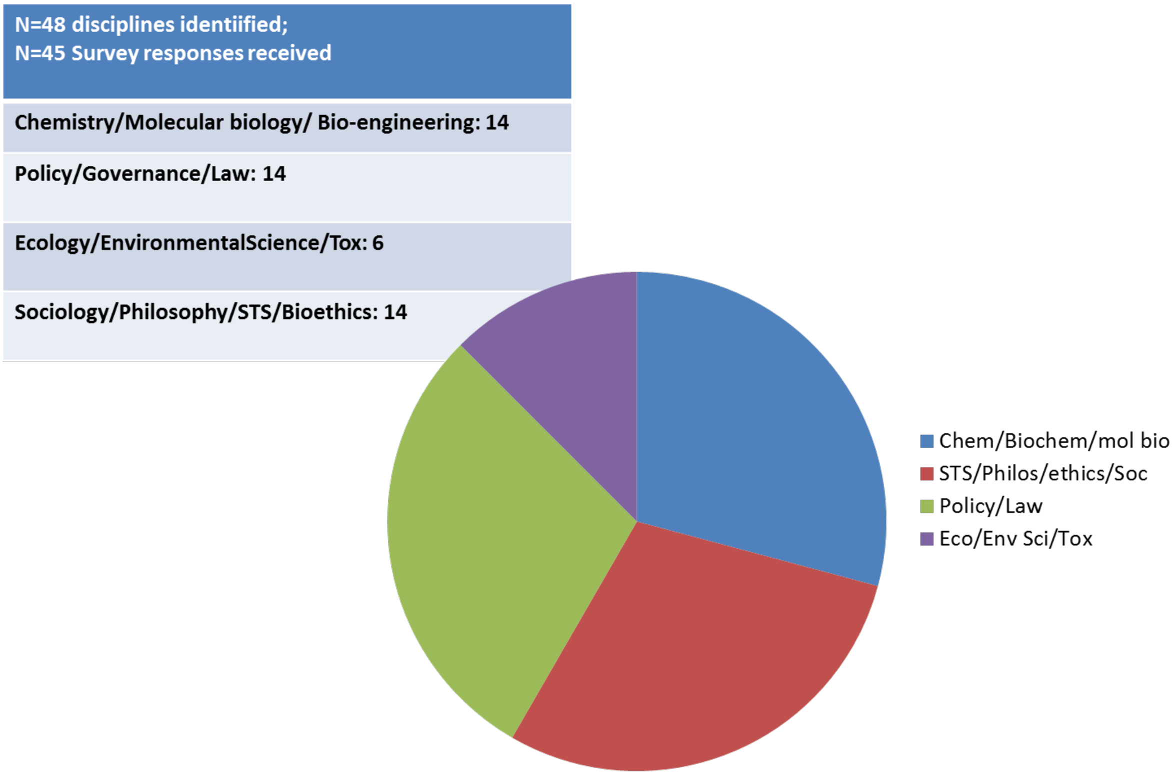

Figure 1: Expert Affiliations.

Semi-structured interviews

In practice, most Delphi exercises try to maintain a three- or four-round limit by utilizing the following procedures: (1) the monitor team devoting a considerable amount of time to carefully pre-formulating the apparent issues; (2) seeding the list with an initial range of options but allowing for the respondents to add to the lists; and (3) asking for positions on an item and underlying assumptions in the first round. Our Delphi consisted of four rounds: a semi-structured interview, a quantitative survey, a face-to-face workshop, and a final shorter survey. This paper essentially uses data from round one (with support from round two, the first survey built upon the semi-structured interviews to formulate questions of risk analysis and governance).

Survey

The quantitative survey method used included questions about potential risks, benefits, and ethical, legal, and societal (ELSI) issues associated with synthetic biological cases. The second round of the Delphi study consisted of a survey with closed- and open-ended questions based on initial themes that emerged from the interviews.

In order to prepare for the rounds of the Delphi study, the participants were asked to read four case studies about synthetic biology applications. Kuzma and Tanji (2010) outlined a case study selection process and approach in a previous examination of detrimental governance profiles built upon in this study. Kuzma and Tanji (2010) state that “different categories of synthetic biology applications may warrant different oversight regimes, and there might not be an appropriate ‘one size fits all’ approach.” They argued “that policy recommendations should be built from consultation with experts and stakeholders of multiple disciplines, and developed in the presence of stakeholders and public citizens” (p. 94). This project is important because it uses the policy Delphi rubric by way of case studies, to meet the call for a more robust policy analytical approach to various synthetic application fields (Cummings & Kuzma, 2017).

Data from experts who participated in the Delphi study were obtained through phone interviews, surveys, and in-person interactions conducted by researchers on the Delphi Study team. The interviews posed questions on general governance and risk analysis needs for synthetic biology and the four specific case studies. The second round of the Delphi study consisted of a closed and open-ended survey based on initial themes that emerged from the interviews (Ndoh, C., Cummings, C.L., Kuzma, J., 2020). Following the survey completion, study participants were invited to a two-day workshop where small and large group discussions and activities were conducted to determine further opinions of risk assessment and governance needs for synthetic biology. Twenty-nine of the study participants attended the two-day workshop. During the workshop, participants completed mind-mapping and concept-mapping exercises in small groups and listed challenges and opportunities for synthetic biology governance as a large group. They completed a second survey and had significant group discussions. As the last part of the Delphi, participants were given a post-workshop survey to complete.

Coding and Recoding

Transcribed data from the interviews in Looking Forward to Synthetic Biology Governance: Convergent Research Cases to Promote Policy-Making and Dialogue, the original Policy Delphi, was then imported into Nvivo software for coding and analysis, and iterative thematic coding was employed to review the transcribed data and find consistent themes discussed by the experts. From these, many subthemes emerged around expert opinions of risk analysis and governance needs for the 4 cases selected. The project team initially coded the interview data using Nvivo 10 to explore and identify thematic patterns, of which 53 were created and coded. A sub-sample of eleven thematic patterns was identified based on their intrinsic relationship with the public (See Appendix A-Sub-sample of 11 original thematic patterns). These 11 thematic patterns were then explored for deeper thematic patterns using the crosstab analysis process, and 13 new thematic patterns emerged concerning concepts of public engagement participation.

These 11 thematic patterns have an implicit relationship with the public engagement process. The subsample of 11 thematic patterns identified in the first wave of coding of the expert interviews included the experts' opinion on *public engagement, public perception, responsibility for governance, access to information, stakeholders other than the public; values and ethics considerations, premarket-post market data collection; experts only-inclusive voices;*

economic factors; anticipated societal risks; and anticipated societal benefits. (See Appendix B-11 qualitative themes).

In the original thematic patterns, several of the thematic patterns already had “the public” as central themes, so they were chosen. These thematic patterns included *public engagement* related to public involvement in decision-making, information campaigns, or risk communication. Public engagement goes beyond simply informing the public; it actively seeks their input and involvement in the decision-making process. Organizations can foster a sense of trust in the community by actively listening to public concerns and incorporating them into decisions. In order to build a more collaborative relationship between the decision-makers and the community they serve, public engagement creates a two-way communication where the public can contribute their opinions and perspectives. This relationship is built on trust and transparency, where the public feels heard and empowered to participate in shaping outcomes that directly impact their lives. (Weingart, Joubert & Connoway, 2021).

Public perception was related to the attitudes and beliefs of inexpert audiences. Public perception is how the public understands and views a concept or technology that can significantly impact society. It is crucial to gain support and acceptance for a concept or technology. Factors influencing public perception include personal experiences, beliefs, culture, information exposure, awareness, benefits, and environmental impact (Cobb, 2004; Durant, 2005).

Stakeholders other than the Public, defined as identifying persons and organizations who are, or will be, influenced by synthetic biological technology, also include shareholders who have some voice in developing and using synthetic biological technology. These are people or groups who can affect or are affected by an organization's success. Stakeholders can include shareholders, employees, board members, volunteers, funders, and customers. Some publics can become future stakeholders. Stakeholders and the public require different communication strategies. Stakeholder engagement can be used to make better decisions by incorporating the diverse views of those affected by the decisions. However, stakeholder engagement can also be used selfishly, wasting time and frustrating stakeholders (Grunig & Repper, 1992).

Premarket—Postmarket Data Collection is defined as identifying data collection efforts or data needs as they are portrayed either premarket or after the synthetic biological technology has been disseminated for commercial or consumer (public) use. The relationship between the public and premarket-postmarket data collection is that the public indirectly benefits from the process by gaining access to emerging technology while also being protected by the ongoing monitoring of safety and effectiveness through postmarket data collection. This can ensure that any potential issues are identified and addressed after the application of the emerging technology is released to the market. Striking this balance prioritizes timely access to emerging technologies and public safety. By allowing data collection to occur postmarket, the public can access emerging technology faster, mainly if it addresses critical needs. The post market data collection process acts as a safety net, enabling regulatory agencies to take action if serious adverse events are identified after the emerging technology application is on the market, potentially leading to product recalls or labeling changes. Striking the right balance between premarket and post market data collection is crucial to ensure timely access to new technologies while minimizing risks to the public (Institute of Medicine, 2007)

Experts only—inclusive voices defined as in-group versus outgroup defining statements that are either inclusive or exclusive of outsiders to expert groups (outsiders being all other publics). The "deficit model" of governance assumes that the public lacks sufficient scientific knowledge and understanding. This can lead to a belief that the best way to address societal issues related to science and technology is to simply provide more information from experts. This model assumes that experts must fill the knowledge gap to gain public support for scientific decisions and policies. Historically, this results in a top-down approach where the public is seen as passive recipients of information rather than active participants in decision-making (Loureiro & Hugo, 2024). Allowing the public to contribute their perspectives and concerns, thus promoting a more democratic and inclusive approach to policy creation, results in a participatory governance model. Science and technology play a crucial role by enabling citizens to actively engage in decision-making processes related to scientific advancements and technological development, especially when dealing with complex issues with potential societal impacts (Kaplan, Farooque, Sarewitz & Tomblin 2021).

Anticipated Social/Societal Risks which had been defined as identifiable risks for society due to the synthetic biological technology. Scientific discoveries often lead to developing new technologies that can significantly impact society. This relationship also presents potential risks, including unintended consequences, ethical dilemmas, and potential misuse of advanced technologies, particularly in areas like artificial intelligence, biotechnology, and nuclear power, which could lead to societal disruptions if not carefully managed (Dhirani, Mukhtiar, Chowdhry & Newe, 2023). Developments like genetic engineering and artificial intelligence raise ethical questions regarding privacy, autonomy, and potential misuse. Rapid technological change can lead to job displacement, economic inequality, and social unrest if not managed effectively. Advanced technologies could be used for malicious purposes like cyberattacks or the development of destructive weaponry. Potential risks can include unforeseen consequences, such as new technologies having unintended negative impacts on society, the environment, or human health, which may not be fully understood until widespread adoption. (Poel, 2020).

Anticipated Social/Societal Benefits are identifiable societal benefits due to synthetic biological technology. Science and technology are deeply intertwined, providing the theoretical foundation for new technologies. In contrast, technology acts as a tool to test scientific theories and make discoveries, ultimately leading to societal benefits like improved healthcare, communication, transportation, and economic growth by applying scientific knowledge to real-world problems. Anticipated societal benefits can include enhanced quality of life through technologies like advanced communication systems, renewable energy sources, and smart home systems can improve daily living standards; environmental sustainability by using scientific research and technological advancements can help address climate change and environmental challenges through cleaner energy sources and sustainable practices; enhanced safety and security devising advancements in surveillance and security technologies can help prevent crime and protect citizens; economic growth in the form of technology innovation can lead to new industries, job creation, and increased productivity; access to information and education by utilizing digital technologies provide widespread access to knowledge and learning opportunities; and improved healthcare in the development of new drugs, treatments, diagnostic tools, and medical technologies to combat diseases and improve the public outcomes (Lipizzi, 2024).

Responsibility for Governance was defined as the identification of stakeholders who should be in charge of governing synthetic biological applications. In order to ensure transparency, participation, and responsiveness to the public's needs, the relationship between the public and responsibility for governance has to be a symbiotic relationship where the public holds the government accountable for its actions and decisions. In contrast, the government is responsible for acting in the people's best interests. The public can demand justification and explanation for policies implemented to hold government officials accountable for their decisions and actions (Bertelli, 2012). Governments are expected to be open and accessible, providing information about their activities and decision-making processes to the public. Citizens can engage in the decision-making process through public hearings, surveys, and voting, influencing the direction of governance (Campbell, 2023). The public's influence on governance is directly tied to feedback and engagement.

Access to Information was defined as the access or lack of access to relevant data and information about synthetic biological technology, including but not limited to the desire for more information. Access to information allows citizens to make informed decisions, participate in public discourse, and monitor government activities, thus empowering them to engage in democratic processes actively. The public's ability to access information held by the government or other institutions enables the public to hold governance structures accountable. The more access to information the public has, the greater their ability to actively engage with and influence public affairs. (Tejedo-Romero & Ferraz Esteves Araujo, 2023).

Values and Ethics Considerations are statements associated with the relative worth, merit, or importance of synthetic biological technology and its influences; they also consider the “rightness or wrongness” associated with synthetic biological technology and its influences (on the public). Public values represent a collective agreement on the rights, responsibilities, and entitlements of citizens, while personal values are the values that guide an individual's behavior. These values are often formulated in general terms, such as "securing the availability of transport services to all." They can also be stated as goals, such as "ensuring everyone has a bus stop within walking distance in ten years" (Virtanen & Jalonen, 2023). Values and ethics are essential in public administration because they help build trust between the public and government institutions. They ensure that the public receives fair and just treatment and that the collective good is prioritized over personal interests (de Vries & Kim, 2011).

Part 1: Thematic Patterns

. The above 11 thematic patterns were then explored for deeper thematic patterns about public participation using the crosstab analysis process, and 13 new thematic patterns emerged. The 13 thematic patterns identified in the coding of the expert interviews included *information sharing, transparency, apparency, education, outreach, knowledge, equity, social contracts of experts, control of technology, acceptance, comparisons to other countries, similarities to genetically modified foods, and economics.*

Table 1: Thematic Patterns with Definitions.

New Thematic pattern	DEFINITION
1. Information Sharing	Statements related to sharing information, being open with information with different stakeholders, reporting accurate results, financial transactions, etc.
2. Transparency	Statements that inquire about how all information is included and how information is disseminated. How open are officials/stakeholders to the public?
3. Apparency	Statements concerning if intentions and meanings are exposed and readily accessible to the public.
4. Education	Statements about whether the public is/should be educated about science and emerging technology and its applications, including formal educational arenas (such as mandatory classes in emerging technology in primary and secondary education, Collegiate, and University).

Table 1: (continued).

5. Outreach	**Statements about whether outreach efforts (civil juries, town meetings, global online forums) to the public are essential to developing and utilizing emerging technology.**
6. Knowledge	Statements about what society knows: What does society need to know, for instance, how an emerging technology works? How important is it?
7. Equity	Statements concerning how benefits, costs, unintended consequences, etc., are distributed over different communities.
8. Social Contracts of Experts	Statements describing the expectations of/to the public of experts developing these technologies.
9. Control of Technology	Statements refer to whether or not the public controls when, where, and how the emerging technology is used. If not, who does? Why? If so, what are the social implications?
10. Acceptance	Statements about the public's concerns towards utilizing emerging technology, including Whether the public has or will accept technology.
11. Comparisons to other Countries	Statements referencing another country's structural, cultural, operational, and governance framework about emerging technology.
12. Similarities to Genetically Modified Foods	Statements that reference genetically modified food/agriculture as a framework/model for other emerging technologies.
13. Economics	Statements that elicit economic inferences about emerging technology and how those inferences influence decisions.

Table 2 displays quotes from the expert interviews that have been included to demonstrate the conceptual nature of the thematic patterns.

Table 2: Thematic Pattern Quotes from Interviews with Experts.

Thematic Pattern	Quotation
Information Sharing	*"I think what is key when you do risk analysis is that you need people from different backgrounds, people who have different kinds of expertise and knowledge in the room."* *"I really think you need to have people who are active in the domain of conservation, in the domain of biodiversity, of civil society, different layers of society being involved in this discussion…really a more open form of discussion and—and inclusive forms of discussion than we might do for other applications that require a little more of a specific expertise…"*
Transparency	*"With enough transparency on how that work is done, and the outcomes of that work, and acknowledging all, you know, intellectual property issues along the way, that, you know, that really good decisions can be made before an active implementation can take place."* *"There is a need for outreach and some transparency so that the public is aware of what's going on rather than keeping it all a secret"*
Apparency	*"So that intent needs to be clear and we need to be accountable and also responsible about these choices that we are making."* *"Because the major question for public engagement is to be able to explain to the public why you're doing what you're doing."*
Education	*"I think the education of the public is [going to] be really important, and I think it's very important to do this in as dispassionate a way as possible. Otherwise, we're likely to make decisions, either good or bad, based not on facts but on a more emotional basis."*
Outreach	*"One of the ways in which these broader societal issues around oversight can be dealt with is by incorporating these types of projects into the outreach efforts of the synth-bio community."* *"There's a technique that is used in environmental area every now and then called citizen juries, and that's—and then they're a group of just normal citizens are brought in to weigh in on a big decision... they're not necessarily knowledgeable about the area, but some time is spent in educating them about the issue they're facing, and a lot of time is spent facilitating discussions."*

Table 2: (continued).

Knowledge	*"What we don't know, what we do not have, is the data and information that we need to have in terms of how the people who are living in the neighborhood, or how the society as a whole will perceive this because it will have some displacement effects on workers. It may have health effects on workers. It will have economic implications. It will have societal implications, and the winners and losers will not be evenly distributed. So, in those respects, we don't know those kinds of data that we will need if we have to make that assessment on societal, ethical, legal and other grounds. So we will know about the technical feasibility. We will know about its economic feasibility, but what I doubt we will know is societal implications if we are not even set up to capture this data and information from the get-go."*
Equity	*"But all these other kinds of economics, and who benefits from the technology, are people in developing countries being exploited through these techniques and these technologies?"* *"Mineral extraction doesn't usually take place usually in, you know, very affluent areas. So there's some equity issues that probably are going to have to be teased out here, and I think the notion of understanding where these technologies are applied in the context of the communities and or even—you know, rural or, you know, where mining is actually occurring is quite significant and needs to be addressed."*
Social Contracts of Experts	*"... Needs to be built into the actual ethic[al] educations of researchers that although they're not constrained by do no harm type of code, they really are, they should be, try to do no harm. They should be trying to do good for the social contract; they should be aware that they don't know everything and not feel that they have to say that they do. And they should be engaging in kind of value-laden conversations with both the public policymakers and with the public."*
Control of Technology	*"Usually people get concerned if you just have only technical people making these decisions, and so it opens up questions about should there be various different kinds of stakeholders involved in evaluating this technology and if certain things should maybe be labeled as unsafe…"* *"…We think local communities ought to be able to regulate what's going on in their community just as states and federal government can."*
Acceptance	*"…when you start dealing with societal acceptance of these technologies, it doesn't always come down to [when] the risk analysis says there's a very low risk by the calculations. You still can have people vehemently opposed to this technology for a whole set of other kinds of—the values, or [other] reasons…"*

Table 2: (continued).

Comparisons to Other Countries	"*Europe is fundamentally off of genetically modified organisms, because the public relations battle was lost early on and there's a lot of misinformation, disinformation, and not discussion but rather just points of view that are being propagated and I think that could be very detrimental if that happens here. It has exactly the same potential.*" "*In places in South Africa or Brazil you might have indigenous people living right by that site that get water directly from some of these sources that will, you know, where before it was polluted with low levels of metals, and now it might be polluted with high levels of these microorganisms.*"
Genetically Modified Foods	*"I can see basically the same issues that have been triggered with traditional genetic engineering are going to get triggered even if you're dealing with synthetic biology-related variants that might use different techniques or tools."* *"I imagine the people who are already bothered by GMO crops would be bothered by GMO crops that are now being sprayed with GMO microbes. Yeah, so I think those, you know, I guess the issues with GMO microbes, in this case, would really get drawn up into this existing debate over GMO crops."*
Economics	*"I would think that the pro would be if taxpayers knew that their dollars were being spent on this, they would want to make sure that they're not going to be harmed…"* *"Why are we spending all of this money and all these resources on things that are already extinct? We have living organisms now that are actually facing extinction. We could actually put our money into those things that are already living that don't require all this technology that still is not working."* *"Without a financial return on their investment, you're not going to have anything that's going to help sustainability because it just becomes prohibitively expensive and we don't have the public funds to be able to fund this kind of research."*

Discussion

Information Sharing

Within the theme of information sharing, key ideas are found, such as diversity of perspectives, information accessibility, and the need for interdisciplinary oversight. The experts from this study stated that adding diversity to the discussion expands the conversation to include perceptions and points of view that the experts may not have thought of before. Adding a layer of society adds a variety of knowledgeable perspectives and robustness to the discussion and allows for accurate information exchange. Information sharing statements from the experts are related to sharing information with different stakeholders and concepts surrounding data access. One expert stated *"...I would say usually people get concerned if you just have only technical people making these decisions and so it opens up questions about should there be various different kinds of stakeholders involved in evaluating this technology and if certain things should maybe be labeled as unsafe that, you know, whether we should have those kind of folks in the conversation…"* One paper described a criterion of information accessibility as "public participants should have access to the appropriate resources to enable them to successfully fulfill their brief in a participation exercise" (Rowe & Frewer 2000, pg. 15). This paper goes on to further explain that appropriate levels of information sharing or access involves several levels. Access to "information resources (summaries of the pertinent facts), access to "human resources (e.g., access to experts, witnesses, decision analysts)", access to "material resources", and access to "time resources (participants should have sufficient time to make decisions)" must be included in a public...process in order to fulfill appropriate standards (Rowe & Frewer 2000, pg. 15). These authors finally state that any limitations or restrictions to these resources could alter the policy formation process that could result in inequities and inequalities.

The experts in this policy Delphi discussed the need for interdisciplinary collaboration. Experts purported that science is becoming more interdisciplinary. Therefore, information sharing is and will become more accessible and expected across disciplinary scientific study fields. One expert underlined this by stating, "… *techniques about how to propagate and/or how to carry out these synthetic biology or genetic engineering experiments and/or processes are going to be disseminated more and more. The skill to carry out those functions is going to be lower and lower, so eventually, it's going to be capable for many people—sorry, for many, many* *more people than just trained experts to collect these kinds of experiments or make these kinds of modifications…"* They pointed out that different applications require different perspectives, which may assist with how different externalities are handled by even multiple applications of the same technology, as those externalities may not be the same within the application use of synthetic biology. A fundamental understanding of all the issues surrounding a specific synthetic biological technology and its application is achieved through "actively' different and diverse stakeholders. These experts specified that more than technical players need to be invited and involved in the discussion in a meaningful way in which regulatory agencies are beholden to this input.

Experts agree that a change in information-sharing techniques will also need to start from the developmental stage into the oversight stage, such as with the upstream oversight assessment presented by Kuzma et al. (2008). This action may foster a deeper and more fluent level of information sharing between different publics that need to understand the how and why of a specific technology, and even the how and why of a specific application(s) of technology will garner more levels of the following thematic patterns in favor of the public. Concepts of complex scientific developments are complicated to relay, teach, and communicate to different publics. Conversely, the DIY movement is allowing synthetic biological concepts to be more accessible to younger and less educated audiences where "normal" people can carry out the procedures, lowering the skill level needed to achieve "common scientific principles in their kitchen." Experts in this study agree that this presents an issue (i.e., flushing microbes from genetic engineering projects from home down the toilet) and will become commonplace. Experts agreed that regulatory agencies would have trouble dealing with these nontraditional actors in the form of policy versus technology gaps but were not sure how to engage meaningfully. One expert stated, *"…And so how the regulatory structure deals with, in essence, non-traditional actors, so people that are not associated with Fortune 500 companies, government laboratories, university laboratories, or sort of large industrial scale laboratories is going to be a challenge…"* Within this stakeholder discussion, the disagreement or alignment surrounds how the different stakeholders will be decided and who has more weight in the conversation than others. These are classic stakeholder engagement challenges that are still present to this day. The experts in this study discussed that expanding information-sharing paradigms will cause a conflict with proprietary information, intellectual property issues, and how the industry standards of sharing information may affect economic bottom lines. They could not agree on how this particular information would manifest in the future as it presents a dynamic challenge.

Some experts' perspectives include how science fiction plays into the public's thinking on how technology works. Experts stated that science fiction is sometimes how the public can digest future technological scenarios and possibilities in its rawest form: imagination. These future scenario possibilities may be an inside job to scenarios that haven't been thought of. They would be considered "taboo" in the science community but may very well show their face in undetermined and unforeseen negative and positive externalities for several different populations. Another disagreement between experts was the concept of what information needed to be shared and with whom and how open-source initiatives presented ethical, health, environmental, and intellectual property issues within these multi-stakeholder-inclusive initiatives.

Transparency

Many scholars regard transparency to be one of the most critical elements of any public engagement initiative (Rowe & Frewer, 2000). These statements inquire about openness on how and what information is disseminated and how decisions are being made. How open are officials/stakeholders to the public? Scholars have argued that "…by being transparent, it is likely that public suspicions about the sponsors and their motives may be allayed" (Rowe & Frewer 2000, p. 15).

The experts in this study agreed on the ability of experts and decision-makers to be open and honest about synthetic biological developments and their applications during the development and implementation processes to the public. There was also agreeance on being transparent to fellow experts to highlight the need for an increased interdisciplinary paradigm that becomes integrated or the "normal" among synthetic biological development and application implementation. One expert stated, *"…with enough transparency on how that work is done, and the outcomes of that work, and acknowledging all, you know, intellectual property issues along the way, that, you know, that really good decisions can be made before an active implementation can take place. You know, my sense from some of the reading is that there already is some kind of, you know, the beginnings of active implications that, you know, how far along these synthetic organisms are, I don't know at this point…"*

While decisions are being made, experts agree that motives and values come into play. Among the key questions experts should ask themselves is how this technology is being sold to the public and how to ensure that transparency from experts is manifested when meeting with the powers that be who will govern and regulate their actions. Are experts and experts prepared to handle the added backlash and criticism, questioning, and concern that the public may exude due to knowing about the development of synthetic biology? Why do experts want to promote transparency and increased information sharing? Who in the public do we want to share this information with? Do we want to share information and promote transparency to the public to increase public opinion's alignment with our goals? Do we realize that open information sharing and transparency may increase resistance and public scrutiny?

Experts in this study expressed concerns about how transparency at different levels of development and decision-making is necessary for full public participation and a reduction of negative externalities. One expert stated, *"…I think that the risk analysis in this is just we should be, as a scientific community, interested in analyzing the risk of sort of overinflating or miscommunicating our scientific intentions and/or reach…"* Answers to the above questions must be asked and answered in a way that increases public participation and trust.

Experts disagree on establishing the transparency standard with the public which stems from the deficit method of the scientific method and its involvement with the variety of publics. Some experts in the study relayed if these (or particular) publics would even be interested in the information needed to understand the synthetic biological process needed to make an informed decision. More experts in this study disagreed on how to open the public debate about synthetic applications and their different levels of development. Even more experts in this study discussed how the public's fear would affect how transparent experts would or should, consequently would, be, stressing that they "should be careful what to say."

Apparency

Experts in this study discussed how accountability to the public, responsible innovation geared towards the public, and clarity to and for the community are elements in public participation. Apparency is defined in this study as statements concerning how open experts are to the intentions and meanings behind or leading to activities in decision-making and whether these intentions are readily accessible for public consumption.

Many would argue that this is a facet of transparency or even information sharing. However, the researcher would argue that the concept of apparency is indeed separate from that of transparency. For example, Rowe & Frewer (2000) stated that "if any information needs to be withheld from the public, for reasons of sensitivity or security, it would seem important to *admit the nature of what is being withheld* [transparency] and *why* [apparency], rather than risking the discovery of such secrecy, with subsequent adverse reactions" (pg. 15). Arguably, admitting the nature of an action or decision does not also need to include the reason behind the decision made. What happens when the public does not agree with why experts are researching the topic? These experts stressed that open communication that explains why and what is being researched and developed helps educate the public, leading to more inclusive discussions towards synthetic biological technology and its applications.

Experts in this study agreed on the importance of apparency and that it must be intricately involved in several topics across the spectrum of synthetic biological applications. This list of topics included intellectual property; benefits and negative externalities (specifically who will get what and how these benefits/risks will be distributed); how that decision is being made; timeframes in development; research and implementation; allocated resources; presentation of scientific concepts behind the product; intentional uses of the product; and potential applications of the technology. One expert underlined this stance by stating, "…*And we think that one of the ethical issues is that the public should have full information on the health and safety impacts of these technologies. We think workers should have full information on it…"* Experts in this study also discussed "*making the public less afraid of science and technological concepts*" and "*eliminating the hype*" surrounding the science involved in the development of synthetic biological. Questions were raised as to what level of apparency is being used when trying to change the presentation of the synthetic biological application to appeal to the emotional associations of the public.

Where experts diverged was how industry-related development of synthetic biology would be affected by the level of apparency being called for versus how apparency will affect the processes by which technology developed with public dollars. Experts disagreed that there would be more scrutiny and/or resistance within either strategy. Experts agreed that a more robust public reaction towards why certain synthetic biological applications are being developed or explored on a case-by-case basis creates more scrutiny for many experts and regulators disrupting the current status quo. Experts agreed that if one assumes the “low understanding of the public” then certain assumptions and biases will go into deciding the level of apparency to be given to and shared with the public at large. Experts did not agree, however, on what should be the level of apparency given to the public and for what reasons.

Public Education

One of the ways the assumptions and biases discussed in the previous thematic pattern can be addressed within the realm of public education, therefore creating a technologically astute “public” within already existing systems. As such, education of the public is another hot topic among scholars who discuss public engagement models in science and technology as well as this exploratory study. The expert statements about *Education* encompassed if and how the public is/should be educated about science and emerging technology and its applications. These statements address the “level of scientific knowledge, the amount of education, and the content of education,” as other studies have done (Bak, 2001, p. 780). Experts in this study indicate that education is of the utmost importance in combating any misinformation issues and in collaborative discussions that significantly reflect the values of the public. One expert stated,

"*…how are you ever going to explain some of these technologies to the public? So, if you want to have a broader societal discussion about them, how do you? We see this with genetic engineering. How do you get a good discussion about genetic engineering when people don't know how experts have manipulated crops generally…How do you get people to understand the technology enough to have a good discussion about it, and how do you put it in context with other things? So part of that research, or that engagement, has to really involve education.*"

Part of the reason it is such a controversial topic is that education is one of the main points of the deficit model, i.e., the higher the education, the higher the predicted support of scientific applications within a societal context (Bak, 2001). Dewey argued that education was the necessary medium that should be used "to equip citizens to fully participate in democratic life" (Dewey 1922, pg. 1523, as stated in Priest and Greenhalgh 2011). Quite a few studies have concluded that "the American public is poorly informed about the topics of science and technology" (Cobb, 2011, p. 1534). Studies have shown that the public is illiterate "about specific issues like nanotechnology" (Cobb 2011, pg. 1534 as stated in the following studies: Cobb and Macoubrie 2004; Scheufele & Lewenstein, 2005; Siegrist, Stampfli, Kastenholz, Keller 2008). Other recent studies "confirm that awareness remains low and that only minimal increases in knowledge have occurred over time" (Cobb 2011, pp. 1534, as stated in Scheufele, Corley, Shih, Dalrymple, & Ho 2009). Research from the literature also shows that "the public is poorly informed about related applications, such as synthetic biology" (Cobb 2011, pp. 1534, as stated in Kahan, Braman, & Mandel 2008).

Given the results of these studies and the push towards public engagement in scientific and technological democratic activities, policymakers must address how the public can "hope to, or even be asked to, shape policies about complex subjects that are expected to affect their lives significantly" (Cobb, 2011, p. 1534) without having accurate information about emerging technology. Although many see the importance of education in a public engagement arena, some of the experts in this Delphi refer to questions of what happens when technical understanding of expert research and development does not change a decision made by the public and why experts are still using education as a way to dismiss the public's involvement in vertical public engagement.

Experts in this study agreed on providing the education necessary for "informed choices" about what is going on in their communities, including the unknowns in synthetic biological applications and the inability to predict the risks. Experts agreed that an increase in the frequency and mediums used to relay scientific communication to the public may produce high achievements in science education, including educating using topics that are already widespread to create educational links and new applications being developed. Experts stated that allaying public concerns to increase educational reach and including scientific ethics education for all stakeholders and the public is the key to adding weight to public opinion and incorporating it into the decision-making process. One expert stated, "*…talk with people in a way that helps raise the educational level so that people are talking from the same facts*, *and then people can decide how they feel about it. Nevertheless, the question is, to what extent is the populous really interested in the nuts and bolts of how they got that copper bowl for whipping up their egg whites? To what extent do other stakeholders who have vested interest in either promoting the technology or being very precautionary about the technologies actually drive the conversation*." The experts in this study diverged on the public's ability to sensationalize "to the detriment" of the synthetic biological development and the scientific communities' willingness to "sale" the safety of technology for economic gain. The experts did not specify how and what to educate the public on but did state that public education would combat experts who justify leaving specific publics out of the decision-making process because the public tends to make decisions based on emotional factors versus facts only. These experts raised questions about what the public is interested in learning and for what purposes.

Public Outreach

This pattern captured expert opinion statements about outreach efforts to the public and whether they are essential to developing and utilizing emerging technology, namely, synthetic biology. Science cafés, focus groups, scenario workshops, deliberative polls, citizen juries, citizen schools, and consensus conferences are a variety of public outreach activities whose goals range from informing the public to empowering citizens to gather input from different sets of the public (Powell & Colin, 2008).

Experts in this study stressed incorporating current research and development of synthetic biology. They gave examples of how these technological developments can be incorporated into our current public policy arenas and forums that provide education and information. They stated that museums, school programs, curriculum development, and citizen juries could be used to incorporate synthetic biology education, transparency, and information into public outreach efforts. They stated that focusing on facilitating and educating the public with the correct and valid data and including the methods of theory-to-practice initiatives are essential to public participation.

Opinions from experts in this study converged when discussing the importance of primary school integration of synthetic biological basic concepts built upon thorough university requirements and the implementation of governmental regulatory education programs. This, they agree, creates future skills in scientific “critical thinking” within the public that will close the large education gap between what the public knows and does not know about synthetic biological concepts. Experts agree that scientific developments should involve outreach and educational efforts and goals. For example, an expert stated in the study that *"…The same applies to science; let's get the kids teaching ethically from the beginning. We have to work a lot on critical thinking we have to have a formal platform in critical thinking and bio ethics in school so that kids actually spend time thinking and developing these goals, these ideas, these attitudes, these skills…"*

Expert opinions diverged on the purpose of the outreach strategy. They raised questions about how to create outreach efforts that create a meaningful conversation around the technology and not just to ensure consensus with synthetic biological developers. Experts also consistently discussed a specific case in this category. Biomining was mentioned several times under this thematic pattern. Many experts raised issues of secondary and tertiary effects. Since no communities are on the land being mined, experts discussed how important outreach efforts might be to the surrounding communities, who may not even be aware of the technology being utilized or how it may affect their daily lives. One expert stated*, "…Well, the broader issue is just the fact that synthetic biology may scare the public. That it—there is a need for outreach and some transparency so that the public is aware of what's going on rather than keeping it all a secret. But as I said with bio-mining it's such isolated areas, it's not around—it usually doesn't take place near any sort of, you know, even residents, cities, or anything. So I don't know that there is a whole lot of concern about it because it's, you know, it's not in somebody's backyard type of activity…* Once an area is mined, how to reestablish that land may call for more focused outreach methods to inform communities of the constant changes inherent in the biomining profession.

Knowledge

The experts in this study focused on what society knows, what society needs to know, who partakes in creating knowledge, and the importance of the knowledge produced, which is included in this thematic pattern. Knowledge is essential not only because it serves as a basis for understanding but also because it is part of how knowledge is created. The experts of this study expressed concerns about whether there is a link between what experts do not know and what the public does not know. One expert stated, "…the issue *around these societal questions and oversight is a lack of data. And so without any real data…to be able to be able to analyze that, it's going to be difficult to have, I think, an honest discussion in a broader societal con—in a broader society sort of concept to be able to explain what the application is doing, what the dangers are, what the pros are without actually having any data to back that up. Because right now, you know, this application and the other applications are all sort of—it's all theory, and it's not being implemented on a large scale where you have any real data points to back anything up…*"

Some scholars argue that knowledge is "produced through communication" (Lewenstein, 2011, p. 818). Other scholars agree that "knowledge does not exist in some ideal state, but exists only insofar as it has been expressed, and each expression produces different knowledge." (Lewenstein 2011, pg. 818 also included Garvey 1979 and Shinn & Whitley 1985 as secondary sources). The current literature calls for support for collaborative knowledge creation concerning 'what science is.' One paper described the reasoning for collaborative knowledge creation as multifaceted. The author states that,

> "Knowledge is increasingly produced in contexts of application (i.e., all science is to some extent 'applied' science). Science is increasingly trans-disciplinary – that is, it

> draws upon and integrates empirical and theoretical elements from various fields. Knowledge is generated in a wider variety of sites than ever before, not just in universities and industry but also in other research [centers], consultancies, and think tanks. Participants in science have grown more aware of the social implications of their work (i.e., more 'reflexive'), just as the public have become more conscious of how science and technology affect their interests and values" (Jasonoff, 2003, p. 234).

The experts in this study focused on the need for data at several levels within each synthetic application. This ties into the need for environmental justice studies for synthetic biological technological advancement as it relates to the populations that it will affect either as a whole or in part, as in how driverless cars will affect truck drivers, whom the technology will most likely displace. They discussed how these studies need to include several layers of discussion, including health, displacement, economics, legal, and ethical layers.

Experts stated in this study that political contexts play a massive part in what is considered knowledge, specifically relevant, unbiased, unfiltered knowledge. Using prior, well-known scientific knowledge is needed to bridge what is unknown in synthetic biological applications, make connections, and create acceptance. Experts agree that the powers that be have not provided adequate, current, and relevant knowledge to the public or those who interact or act on behalf of the public. Experts stated that data insufficiency exists for complete knowledge transfer to governmental regulatory agencies and the public. Full knowledge transfer would include data and implications from scenario development to explore uncertainty and risk analyses. One expert said, *"…And I would think also in terms of the risks and benefits this is also the whole genetically modified foods debate is also one that's just so political it's—and political in terms of all kinds of debates about who, you know, the economics, who benefits, or whom it* *exploits. I think they're often cast as, you know, providing new food sources, and all of this. Then other people counter, "Well, it's big Monsanto and these other huge multinationals that are actually benefitting." And so there's a whole kind of economic and political context that underpins the genetic engineering debate that I think you'd also have to collect data and information around that…"*

Experts discussed the effects of science fiction on widespread public knowledge of basic synthetic biological concepts and the expectations of the public reaction to visual cues versus verbal ones. Again, here, the concepts of coevolution of social science research parallel to synthetic biological development are used to create new knowledge and best practices that uncover some uncertainty, identify and minimize risks, explore perception issues, and render solutions that work on a practical level.

Experts disagreed on how or who should compile and distribute current and relevant knowledge or how to convey the details of an application, especially if different disciplines of science went into the development of the current synthetic biological application, which compounds the level of difficulty of the scientific principles and/or the complexities in risks and benefits from the synthetic biological application. Questions were raised about what the public needs to know when they need to know, and why the public needs to know.

Equity

This thematic pattern captured expert statements concerning how benefits, costs, and consequences are distributed over different communities. Social equity is the ability of members of a society to have equal access to opportunities and benefits. Unlike equality, social equity does not seek equal distribution among members of society. Social equity is closely related to social justice and fairness and is often used interchangeably. This is a common mistake because what is equitable may not be considered just or fair. Thus, how equity can take varying forms. Many fields have addressed social equity in practice, such as health care, education, and public administration. In the case of public administration, equity is achieved through procedural fairness, distributional equity, consistency in processes, and the elimination of outcome disparities (Norman-Major, 2011). Equity in science and technology development and decision-making can also highlight the facilitation of equity in scientific relationships, responsible innovation, equitable product marketing and pricing, and incorporation of equitable business practices.

The experts in this study addressed the question of who could decide what is equitable for the public. They recognized that technology is applied in the context of specific communities that make up the whole of society. They stated that they recognized that technological synthetic applications would mean something different to each community across various cultures, needs, demographics, and values systems. This indicates that the externalities are different for these communities; without their perspective, making decisions with these communities is impossible and not creating negative or positive externalities.

Experts' opinions under this thematic pattern converged on several topics, including how the benefits being distributed to the public and corporation(s) involved in the synthetic biological development and implementation, as well as political and economic contexts, influence the equitable distribution on various levels. As global landscapes change, who is a political superpower or an ally of one may influence who gets equitable accessibility. Experts explored questions of the perception of the developed countries, including exploiting the resources of the developing countries, as well as how equity relates to values systems and norms that have never been considered or have not been utilized to create an even playing field for all stakeholders.

Questions were raised about what level of power or control communities should have over the development, regulation, and/or implementation of synthetic biological applications used in their community, directly or indirectly affecting those communities. From the study, one expert stated, "*… we think local communities ought to be able to regulate what's going on in their community just as states and federal government can.*" Another expert went on to say, "*…The other thing is it relies too much on technology and not as much on human behavior and it sort of, then, raises the more ethical question of; can people do as they please and don't make any change in their behavior, act irresponsibly, and there could be some kind of a no matter what. So it sort of, in some way, gets an out and we sort of, instead of dealing with the problems, because a lot of the food problems is not just a matter of production but also a matter of distribution and corruption and all of these other things. So it doesn't address those systematic issues and raises a false hope so I think whatever we decide to do with these plant microorganisms that's trying to address the greater good of feeding hungry people we need to sort of find a mechanism to bring them onto this discussion, and oversight, and regulation and assessment so the path we choose is the path that is desirable for the end user and not the path that we think is desirable or most expedient for us in the first-world…*" Experts did agree that these communities should have access to equity by being able to demand their tradeoffs, benefits, and determine their level of acceptable risks/hazards. One expert asked how do we as a society determine who will ultimately be affected by the synthetic biological application if there is difficulty in predicting what information will lead to developments. Experts highlighted that definitions are changing due to more equitable distribution on various levels. These definitions include oversight, community, values, positive & negative externalities, proprietary information, and intellectual property.

Experts disagree on who would be responsible when the unknowns and the unpredictability of the synthetic biological application manifest themselves; and who is responsible for rectifying those issues when they arise. Experts disagreed on the levels of equitable distribution in development decisions versus positive/negative externalities versus accountability. One expert stated *"…Where does the responsibility lie?" So the question is; where does the desirability come from? We are letting the experts, or Monsanto…of the world define what is desirable. Still, we're doing it in the name of people who will be using this, who we haven't actually posed these questions to, and how it will affect their livelihood, quality of life, and way of living. So I think that needs to be incorporated in a manner that would not create something that creates greater inequity or new groups of winners and losers. So I think the broader societal question here is that it's the first-world deciding how to deal with a third-world problem. Still, the third-world doesn't have a seat at the table or to bring in that we value one type of knowledge, but there may be other types of knowledge that can also address these problems we're trying to solve…"* Some experts discussed how research should be driven by the needs of people experiencing poverty and highlighted the need for all stakeholders to consider equity issues from many angles.

Social contracts of experts

The experts in this study focused on describing the expectations of/the public of experts developing these technologies and trying to anticipate them. In the past, the expectations of the development of science and technology were in the hands of experts. Jasanoff 2003 stated that "experts [were expected to be the entities that] establish the substantive aims as well as the intellectual standards of research" in science and technology (pg. 227). She states that "as long as the 'social contract' held sway, no one questioned whether safeguarding the autonomy of experts was the best way to secure the quality and productivity of basic research" (Jasanoff 2003, pg. 228).

This context has recently been challenged as science and technological advances become more conducive and inclusive in the general public's daily routine. The expectations of the social contract between experts and the public have shifted more to a model of power-sharing. That is to say that not only does the model of public engagement need to include activities that cipher its input, but that input should influence policy, not just be used to quiet the public and garner "trust" so that experts can do what they please. Powell & Colin 2008 and Seifert 2006 postulate that public engagement practices "would need to have some political weight to attract attention and catalyze broader public debates" (p. 130).

These authors argue that this public engagement model would require "academics and political decision-makers to allow for its outcomes to be unpredictable and to have real consequences, or, in other words, for a sharing of power" (p. 130). This model results in both parties influencing knowledge creation and policy decisions. Powell & Colin (2008) and Grunig & Grunig (2001) state that "the degree to which parties agree on who has rightful power to influence one another" is a critical component of effective engagement with the public, and the healthiest relationships exist "when organizations and public have some degree of control over the other" (pg. 130). Is it the expectation of the experts to think about how their research affects the public?

The experts in this study discuss the concept of including educational elements in training researchers and policymakers, which include opportunities to examine their role and contribution to the social contract. They discussed how the social contract lends itself to be addressed within the development of synthetic biology with value-laden conversations and eliminating the taboo nature of discussing values within the scientific development context of synthetic biology. They discuss "adding education to the educated" through interdisciplinary exposure and collaboration and training in how to translate synthetic biology developmental applications into what those applications look like in a practical sense, how they will be used, abused, controlled, and disseminated.

Experts agreed under this thematic pattern about "reassuring the public the technology is safe." Still, they did not agree on the specific levels within this reassurance such as safe for who, safe for how long, and the parameters of the definition of acceptable risks/hazards. Experts agreed that ethical training for researchers should be an industry standard and that there will be different effects on business synthetic biological development and synthetic biological development to enhance the life of the public that can access it.

Experts agree that there is an inherent conflict between experts, the public, the government, and advocacy or lobbying groups. One expert stated *"…So I think the biggest risk here is the mutual interest of the experts working on de-extinction and the experts working on environmental assessment and public and government groups that control public opinion or the decision of which organisms to bring back, all of those groups could be in conflict, and I think what's important here is having a method of based on the environmental requirements and the initial technology. For example, if we just brought back the wolly mammoth, that might be the easiest and most popular, but in terms of environmental impact, it may be more detrimental than positive…"* This conflict greatly influences the status quo of the motivation behind synthetic biological development.

Control of Technology

These expert statements refer to whether or not the public has control or influence over when, where, and how the emerging technology is used. The experts talked about several concepts, including if not who does, what are the social implications of who controls the technology, who decides what kinds of innovations are released, and who is responsible for the consequences of releasing new, controversial, or potentially risky technologies, what obligations do we owe our fellow citizens, especially when they disagree with the science such as vaccinations or genetically modified food processes.

Experts in this study made mention of how synthetic biological development and decision-making do not usually happen in communities where resources are plentiful and access to said applications is readily expected but can still expect to be significantly affected by synthetic biological applications. They stated how often technology disproportionately distributes negative externalities to the public while distributing positive externalities to the decision-makers, i.e., developing a forest in which a tribe lives and dwells.

Experts agreed on a specific point but at varying degrees, in this thematic mode. They stated that missing this step could impede the development of synthetic biological technology and its applications, taking into consideration, especially if those value systems differ from those of the scientific community, who should make the decisions on control. They agree that societal discussions about synthetic biological should include whether some technologies should move forward and to what degree or go back to the drawing board and if that technology is sustainable and economically feasible, according to public need. Highlighting this point, an expert stated that *"…and so what you end up doing, you know, by not governing the whole package is you—you just end up with a public debate that gets shriller and shriller because you don't want to regulate* *what you're doing. So not—not regulating well you get a—a shriller and shriller public debate, you have bigger arguments between the US and Europe, bigger arguments between the US and Japan. And you end up having market strategies, you know, "Don't buy this crop, you know, don't buy this product because it's—it uses this." Which is the, you know, the boycott strategy is not an ideal governance option, but if the proponents don't—don't make for good governance it may be the only option people have left…"*

Experts agree that there will be knowledge versus power asymmetric conflicts between regulators, corporations, and the public as synthetic biological technology is filtered through the public(s). These conflicts include who controls what and how to utilize a checks and balances system that highlights and honors the value systems of all stakeholders. This control, experts pointed out, will change the definition as per the case, expert level, and location of implementation/deployment of said technology.

Experts diverged on whether regulations of these synthetic biological applications should become localized and community-based versus national or international standards. They also questioned to what degree a model should become a universal standard of development, research, and implementation and if this model should be fluid, being modified per application and/or as new synthetic biological technology emerges. Questions were raised as to how the perception of the public's "tendency to sensationalize" new technology is a conflict that highlights the control of technology or the control of the public through technology. Experts agree that there are "levels of control." When technology becomes commonplace, there is less control universally and, therefore, harder to regulate.

Experts in this study discussed how control of technology relates to equitable distribution of benefits and risks/hazards, control of information and information sharing, and apparency deficits, which bridge the equity thematic discussion. Lastly, experts discussed how there may be a perception that the public has control of the technology but may have less than is thought. One expert stated, "…*I think from the public's perspective, they probably want to know what they're consuming, and it seems—that just seems to be the history of the—for the genetically modified foods controversy, people just want clarity and want to know, and they want to have that choice of whether they want to eat those foods or not..."* Is the concept of the control of synthetic biological technologies being used to increase and influence the decision-making power of the public, or is it being used to garner a path toward acceptance of said technology that would result in experts having more autonomy?

Public Acceptance

These expert ***s***tatements highlight the concerns of the public regarding the utilization of emerging technology and whether the public has or will accept the technology. One way that policymakers have assessed public acceptance of emerging technology is to identify 1) the public's willingness to accept/buy/use emerging technologies, including synthetic biology; 2) the prior belief systems and information barriers surrounding the emerging technology (perceived benefits versus perceived risks). Both of these factors can play a crucial role in the public's acceptance of any given emerging technology, including synthetic biology applications. One expert noted "…*Again I think this is going to be a huge policy—public policy issue which generates a lot of fear on the part of the public with creating new species, or trying to recreate species. There's always been a great deal of fear associated with cloning of animals, and this is just a—takes it a couple steps further. There would have to be I would say a whole lot of public engagement, and I just think there's going to be a whole lot of public objection to this particular application as well…."*

The consumer's willingness to accept/buy/use emerging technology can be used to influence how the governmental policies are shaped, as a willingness to accept/buy/use these technologies is a good indicator of the public opinion towards these synthetic biology applications. Previous research results show that consumers are willing to accept products that enhance health benefits at a price premium (Heiman 2013). Some studies show that "consumers are willing to trade risk for benefit when benefits are tangible and significant, and therefore the development and introduction to the market of emerging technology is believed to be a promising avenue to accelerating …acceptance" (Heiman 2013, pg. 47). Willingness to accept/buy/use trends can assist policy makers in answering questions about how demographical variation affects public opinion on emerging technology. Some of these questions include (but are not limited to) the effect that socioeconomic levels have on public opinion of emerging synthetic biology applications; the effect that race and/or ethnicity affect the public opinion; if gender has a statistically significant effect on willingness to accept/buy/use synthetic biology applications; as well as the effects of age on public opinion on novel technologies.

Experts in this study discuss the duality of the public (how the public protests yet consumes other technologies) and how that kind of vice will affect synthetic biology and its applications. The effect of prior beliefs on consumer willingness to accept synthetic biology applications has been studied in the past. Most of the findings suggest that "initial attitudes toward biotechnology have a significant effect on how individuals responded to new information" (Lusk, House, Valli, Jaeger, & Moore 2004, pg. 180). The literature stipulates that this kind of behavior suggested that the prior information of the participants in the study, was somewhat negative. Some studies show that "participants who had uninformed prior beliefs about genetic modification exhibited the greatest change in [willing to buy] behavior due to the injection of new information" (Huffman, Rousu, Shogren, Tegene 2007, pg. 203). When information from interest groups or third parties was supplied, a significant change in the willingness to buy behavior of uninformed participants resulted (Huffman, et. al 2007). Studies have shown that a different effect occurs to those who have informed prior beliefs or set beliefs. Relatively no change in willingness to buy behavior occurred when any type of new information was injected into their knowledge base (Huffman et. al 2007).

Experts agreed that the "novelty" of processes and synthetic biological products will always garner the public's concern and that overcoming the negative aspects and fears of the public will ease that concern. They agreed that value systems that lead to acceptance or environmental justification of a specific technology must be incorporated in deliberative democracy and participatory technology assessments. Clarity paves the way to trust and the lack of clarity increases distrust, leading to low public acceptance. Experts stated that it would be difficult to garner acceptance of the synthetic biological technology if the corporation benefits from its development or implementation. The public's level of acceptance increases as more concerns are honestly and ethically addressed. Several of the thematic patterns already discussed seemed to merge here in an intriguing connectedness.

Experts disagreed on whether or not risk analyses should incorporate value systems of localized communities. One expert stated that *"…have considerable concerns that – not necessarily of governmental regulation and oversight, but I do have concerns that sometimes those government oversights are driven less by the actual risks than just by perceived or misconceptions about what the technology is…"* Questions were raised about addressing the public's concerns to garner more public acceptance cross the line into control of technology issues.

Comparisons to other countries

These are statements made by the experts in this study that reference another country's structural, cultural, operational, and governance framework concerning emerging technology. This thematic pattern encompasses the idea of diverse populations and cultures. Public perception and debates in the European Union and Mexico surrounding genetically modified or nano-engineered foods have highlighted the importance of public engagement (Stares 2009; Durant and Legge 2005; Aerni, 2013). Scholars now realize that many public perceptions are tied to the cultural associations of that public. While these "perceptions" have been used to discredit the public's opinion and justified its exclusion from decisions about science and technology, others have examined these concepts and concluded that these perceptions hold weight for one reason or another.

(Sturgis & Allum 2004 and Douglas & Wildavsky, 1982), have postulated that:

> "Fears about new technologies are functional because they provide a basis for maintaining cultural associations. In other words, people select risks to worry about according to the norms of their social milieu rather than responding to supposedly more "objective" hazards. Others have shown that perceptions of technological risks are related to certain worldviews or the holding of certain core beliefs and values such as environmentalism. In none of these conceptions is the perception of risk dependent primarily on one's level of scientific understanding" (pg. 57).

Experts in this study discussed how actions in other countries affect how synthetic biology applications are decided upon and how it is different than the United States; how will the status of the countries where these decisions are being made (industrialized versus under-industrialized) affect how synthetic biology applications are decided upon that affect a global audience while still affecting individual communities here. One expert stated *"…Again, in some countries, the United States and Australia, etcetera, sophisticated structures allow tracking the development of these technologies in real time and permit auditing and knowing what's going on in the fields. In other places that tend to be associated with heavy metal mining that might not be the case and some of the risks have to do with these regulatory differences across the world…"*

In this thematic pattern, experts commented on definitions of what it means to be a developing country versus a developed country that can change due to either the development or access to emerging technology. Differences in relationships between how developed countries interact with other developed countries and how developed countries interact with developing countries were discussed. Experts agreed that trade and economic interactions with and between countries can change with the introduction and access of new technology, synthetic biological would not be any different. Issues that the experts highlighted included how different synthetic biological applications would have various benefits and risk factors, therefore, it is hard to determine or predict outcomes on a universal scale but there were also possible synthetic biological applications that may be applied globally but issues of equity arise here also. One expert noted *"…Food production globally is an issue and will continue to be an issue over the rest of the century and this is one technological approach that could greatly enhance the ability for the world to feed—the people of the world to feed themselves…"* Historical treatment of developed countries over developing countries leads to environmental justice issues and practices to be developed as multinational corporations drastically affect the global landscape of which countries get access to the technology and to what degree. Control of technology, distrust, capitalism versus socialism, and "selling the technology" were common themes discussed by the experts in this study.

Similarities to genetically modified foods

This thematic pattern is oddly specific. As plant microbes were one of the cases chosen in this study, it is reasonable to assume that many experts, as well as other stakeholders and publics would think of food. It is important to note that the science of genetically modified food has been of topic of public discussion and academic discourse for many years but it is still changing and advancing, therefore it is also reasonable to assume that it may be a topic of discussion in this study. These expert statements refer to genetically modified food/agriculture as a framework/model for other emerging technology due to its continued longevity, history, and constant change. One of the central premises of these statements is who is representing the public in how genetically modified foods are perceived.

Some researchers believe that "it is ultimately not the weak attitudes of taxpayers and consumers that matter to [policy makers] but the strong attitudes of the noisy anti-biotech movement and the reputational risk [these anti-biotech organizations] represent for political parties and big corporations" (Aerni 2013, pg. 1131). These special interest groups or anti-biotech organizations have acquired the trust of the public "by claiming to represent the public interest" (Aerni 2013, pg. 1131). The consequences of weak or nonexistent public opinion on emerging synthetic biology applications can lead to special interest groups taking control of the direction of the public policies related to these applications. The formation of an iron triangle occurs, where special interest groups "are increasingly courted by politicians who represent power and retailers who represent money. Both need public trust as a source of legitimacy for their actions" (Aerni 2013, pg. 1132).

The policymakers can reason the influence of the "extreme views of activists" within special interest groups "not because they represent the public interest but because they are likely to make [legislators] look good in public" (Aerni 2013, pg. 1132). This reasoning can lead to public policies on emerging technology that are not created simply for the benefit or protection of the public, but to support special interest groups' agenda and political self-gain. For example, specific applications of genetic modification or nano-engineering such as genetically modified rice referred to as "golden rice" (genetically engineered rice fortified with higher levels of β-carotene) could be a cost-efficient solution to addressing the Vitamin A deficiency issues in developing countries. The opposition of these genetically modified crops, from organizations such as Greenpeace and Friends of Earth, may directly influence policymakers where public opinion is weak. This results in the creation of public policies that contrast the benefits to the directly affected public, those afflicted with Vitamin A deficiencies. Some leaders in emerging technology governance proposed that "retailers and politicians should have the courage to stop being mere cheerleaders for a dubious cause and start asking critical questions" (Aerni 2013, pg. 1132). How will other controversial technologies affect how synthetic biology applications are decided upon?

Experts discussed some of the connections between synthetic biological to genetically modified foods and its processes in development, research, and implementation. Experts pointed out that the public may have similar reactions to synthetic biological concepts as they did to genetic engineering of food and food products. An expert in this study stated *"…are very similar to the GM debate, and I think we have an opportunity here to have a better societal discussion around these types of technologies, particularly when you're dealing with—with engineered plant microorganisms which are going to be for food products. And so I think if we can design a better engagement strategy around these—this application, we'll have a better understanding of how large society feels about these particular technologies…"* Some of those connections include mixing in different types of stakeholders, control of technology issues as genetically modified food is seen as big business benefiting corporations more than the public at large, transparency issues, as well as the needs of the poor driving synthetic biological development. Experts pointed out that synthetic biological may include organic elements and how this redefines what it means to be synthetic and organic. Experts discussed how there will be stronger reactions to visual products (de-extinction) and non-visual products or processes (plant microbes).

Experts diverged on how to describe synthetic biological in terms of variants of genetic engineering and how to apply regulatory elements to synthetic biological such as the precautionary principle. Lastly, experts questioned the extent of the public's involvement in the conversation if synthetic biological principles are not part of the product but just the processes.

Economics

The expert opinions that elicit economic inferences about emerging technology and how those inferences influence decisions were categorized in this thematic pattern. The experts made mentions of different sources and kinds of economics produced by synthetic biology and its applications and how one kind is different than the other when comparing communities of race, class, and religion as well as how different the economics are different as per each application of the synthetic biological development. They discussed how these economics are used by these communities to increase the social capital of each said communities.

Experts stated that economics is defined as time, talent, and money. For example, what are the ancillary costs of the release of these synthetic biological applications in the environment in 5, 10, 20, 100 years? The DIY movement will have significant impacts on the multinational corporations and their bottom line as well as change the landscape of what it means to be able to develop synthetic biological if it becomes as common as the chemistry set did in the 1970s. Economic gains and relevance from synthetic biological applications may look different in different countries and when on a local or global scale. The addition of non-traditional actors in the decision-making process changes the definition and reach of these economic gains and relevance. This decision-making process includes governance, industry standards, and equity distribution. Economic gains and economic relevance also will be affected by whether the synthetic biological application is backed by public funds or private corporations. Expert opinion converged when discussing how synthetic biological can highlight issues of class manifested by power struggles between the wealthy and the poor of control of technology, accountability and transparency, and equity.

They questioned if certain synthetic biological technologies should be free or available under the socialism model of governance versus a capitalistic one (medical and food technologies) and if experts should be held accountable to technologies that present no benefit to society as a whole (technology used in T.V.s and cars). Many of the experts poised the question of how economic hazards for the public are taken into consideration in risk assessments of emerging synthetic biological technology including displacement of workers and other employment effects, creation of disenfranchised communities, and perpetuation of lack of access to communities already negatively and disproportionately affected. One expert noted in the study *"…as far as the data is concerned, obviously the technology is being developed and it's used so it will be those kind of effects, initially, in terms of the risk. The ones that are set up are basically to measure the people who are in the vocation and people who are in the immediate vicinity of the mines of where this technology is being used and so forth, but what we don't know, what we do not have, is the data and information that we need to have in terms of how the people who are* *living in the neighborhood, or how the society as a whole will perceive this, because it will have some displacement effects on workers. It will have economic implications. It will have societal implications, and the winners and losers are not going to be evenly distributed. So, in those respects, we don't know those kinds of data that we will need if we have to make that assessment on societal, ethical, legal and other grounds. So we will know about the technical feasibility. We will know about its economic feasibility, but what I doubt we will know is societal implications if we are not even set up to capture this data and information from the get-go…"*

Experts disagreed heavily on whether synthetic biological applications needed a top-down or bottom-up governance structure and how economics may affect long-term research into risks. They also disagreed on how much society would be willing to spend to benefit a few versus the utilitarian view of distributive justice. Cozzens (2007, pg. 87) states that the "dominant, if implicit, rationale for scientific and technological policies and practices is utilitarian, and they carry with them a utilitarian notion of distributive justice". In the utilitarian view, fairness is implicit in its principles. According to Cozzens (2007, pg. 87), "set of social arrangements is fair as long as it increases total well-being". This school of thought relies on others in the public to assume that the public will make small sacrifices to the individual as long as it benefits the whole of society and that scientific and technological development policy must "consider its own intrinsic contributions to distributive dynamics (Cozzens, 2007, pg. 89)" of how it will affect the whole of society and how different publics will influence other communities within that whole. Lastly, experts laminated over what mechanisms would be used to weigh all these different costs.

Conclusion

Thirteen themes were identified that related to expert views on the public and their participation in the research and development of synthetic biological applications. The 13 thematic patterns identified in the coding of the expert interviews included information sharing, transparency, apparency, education, outreach, knowledge, equity, social contracts of experts, control of technology, acceptance, comparisons to other countries, similarities to genetically modified foods, and economics. Some of these conclusions may not be corroborate much of what has been previously found. They do highlight how experts still view the public and what work needs to be done to actually include the public in meaningful ways in the development of science and technology, which creates more positive externalities than negative ones.

Barriers

Several researchers have explicitly examined the various barriers to public participation (Petts, 2003, 2004; Diduck and Sinclair, 2002; Leksmono, Burnet, Dorfman, Gibbs, Longhurst & Weitkamp, 2007). Jardine, Boyd & Furgal 2009 states that "an assessment of opportunities is incomplete without an examination of the barriers to their creation and utilization". One of the major sets of barriers to a successful process identified is the adequacy of representation. This includes specific impediments such as access to opportunities, disparities among people in their ability to 'get to the table' (including education and knowledge about the issue), and a selection method seen to manipulate membership to result in a certain decision (Stern & Dietz, 2008; Laurian, 2008). Non-representativeness may lead to a loss of credibility in the process (Petts, 1995). One of the biggest barriers identified in this study dealt with definitions and elements of safety and selling that "safety" of that technology to the public to increase acceptance. Many experts identified this as a slippery slope where boundaries in control of technology, equity, economics, and information sharing get blurred. Questions were raised as to how deeply the public can grasp synthetic biological concepts and processes, not only to make an informed decision but to continue to be an influential voice within the decision-making process.

Other barriers identified in this exploratory analysis include the actual probability that public inputs influence policy on governance concerning synthetic biology. As found in the previous discussion section, although the experts in this study are open to including the public on a deeper level and moving to a majority mindset of participatory democracy, there is still a lingering deficit model mentality when it comes to the public being allowed to make a deeper impact on the governance of emerging technology, in this case, synthetic biological. The concepts of what knowledge is useful or relevant and how that information is shared are key factors to this barrier. Another barrier is the thematic pattern of equity and the interconnectedness equity has with the embeddedness of capitalism:

"And so I think that that can—that can pose problems and also something for the future as some of these technologies diffuse and start getting used by, you know, people who aren't just members of the traditional life science community. I think that also poses problems for governance, because you can't assume they have the same norms or the same values that let's say people who are, you know, implicated with these norms and the—let's say the academic community would have—a shot at having that use in technology."

Opportunities

An opportunity for more developed models of public participation in synthetic biotechnological development is the willingness of current and relevant experts to recognize the need for enhanced public participation on a variety of levels. Experts in this study expressed an overall attitude of wanting to incorporate values, emotional factors, and cultural norms of many publics and stakeholders to make healthier and better-rounded decisions. Another opportunity is coevolving social science with emerging synthetic biotechnology. Another opportunity is to use the already existing common knowledge that comes with a familiarity of a technology such as genetically modified foods or nanotechnology, to build upon the knowledge needed for an informed decision in synthetic biology cases, gauge public reception based on the history in these present scientific and technological disciplines, and to create a basis public participation for synthetic biology and its applications. One expert stated

"…of what we value and making sure that we have a full and fair discussion on why we should be doing this. And again I mentioned early on that there—there could be some really good reasons to do it, you know, it speaks to our—to responsibility and ethics, but it also speaks to sort of trade-offs. And I think oversight in the development of this technology and implementation of it, we should fully, you know, that should be fully aired."

Barriers & Opportunities

Science fiction was identified as both an opportunity and as a barrier. Science fiction and sensationalized perception of synthetic biology processes and outputs may hold back much-needed development and research and it could also be an opportunity to create better future scenario research that could be used to identify unknown and increase the predictability of synthetic biology applications (Barendregt, et. al. 2024; Bell, 2004). Another opportunity that is also a barrier is the changing definitions as the global and therefore, local landscape changes. Some resistance to the changing status quo may manifest as experts are forced to live in a world that is changing very rapidly.

One expert stated

"You have people now, the IGEM folks who are, you know, high school, college age students all the way up to working professional experts who can access and use some of these technologies, and tools, and methods. And I think that also poses problems for governance where I think in the past governance has been thought about, you can isolate that to let's say an elite academic laboratory or maybe even an elite industrial laboratory but you didn't maybe always have to think about the technology filtering down to the more working level, or the student level."

Another expert stated

"… What I was trying to say is that the actual science and the social science can't take us where we need to go in terms of imagining the possibility. This is where I think there needs to be some type of people who write science fiction, who sort of do this, see all of the different kinds of futures and the possibilities, the kind of world that it may create or destroy. I think this one requires engagement of even the writers and philosophers and people in the media in terms of even broader engagement because this really gets into the essence of how we are imagining our life to be and, based on that, how do we make choices to get closer or away from what we don't want to be."

Most researchers agree that improving public participation activities in risk governance requires a critical examination of barriers. This will enable finding solutions that reconcile differences and rectify deficiencies (Stern & Dietz, 2008). Evaluating and assessing a public engagement model based on these factors may allow policymakers to identify the needs of the public and incorporate the ideals of participatory democracy (Barendregt, et. al. 2024; Bell, 2004). Another factor that may assist policymakers is an insight into how the public may forms its opinion. The acts of speaking and hearing make people active participants in policy debates, rather than the passive audience members that others presume them to be" (Priest and

Greenhalgh 2011, pg. 1522). Dewey argued that education was the necessary medium that should be used "to equip citizens to fully participate in democratic life" (Priest and Greenhalgh 2011 as stated in Dewey 1922, pg. 1523). In Dewey's view, empowerment is the goal of democracy. He argued that information systems should be used to encourage the public to participate in decisions regarding those policies.

Early studies on expert opinions on the public's participation in Science and Technology research development tended to skew towards the public being led by experts and technical experts. As science and technology becomes more embedded in everyday society, further examination led to another school of thought. This school of thought valued the public's investment and knowledge surrounding the impact of emerging technology as well as its opinion in the research and development as it leads to increased critical thinking of the public's contribution in the comprehensive and robust societal decisions concerning research and development of emerging technologies. These contributions help to build the foundational knowledge and structure necessary to address the environmental justice impacts and externalities that accompany emerging technological and scientific developments.

It is important that the public has a say in the development of technology and its governance in order to ensure diverse perspectives are taken into account early on and therefore make it more likely that certain groups will not be marginalized with negative externalities naturally produced by the emergence of new technology.

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APPENDICES

Appendix A: Sub-sample of 11 of 53 original thematic patterns

1. **Public Engagement**: Related to public involvement in decision-making, information campaigns, or risk communication. ”*I mean, I would probably say here it would be similar to the whole genetically modified foods, such a long-standing, ongoing debate. I just don't see it being—I mean, the only thing that might be different is the—with the synthetic biology, it might raise more—it's really our decision now. It's not just partially modified, or people would maybe see it as an—in a very—although again, there's been these different—I know I remember seeing news about synthetic meats. I think that people are now trying to market, and I mean, I think the same kinds of outreach and engagement that have been developed for genetically modified foods are consistently important for turning towards synthetic variance. "*
2. **Public perception relates to the attitudes and beliefs of** inexpert audiences. *"I think this one is going to have a hard PR problem with it; it's like, "We—we made a robot-cybernetic sea lamprey." And like, I think people have images of blood-sucking monsters and then again—or have this idea of like, you know, Terminator, evil robot, cybernetic, you know, like that sort of story sequel.*
3. **Responsibility for governance:** Identification of stakeholders who should be in charge of governing synthetic biological technology. *"So here again it would be—it's the same thing as EPA, USDA, and the FDA, like all the groups that are associated with how we govern genetic engineering technologies. When—where they can be released and—and—and used in the environment—I think those—those are the organizations that would have*

to be involved and—and sort of consider how they—how the existing rules and methods might apply to new technology.

4. **Access to Information**: Access or lack of access to relevant data and information about synthetic biological technology; desire for more information. "*Okay, let me think. I mean, I think this is another one that's going to be similar to bio-mining, where I'd be interested in having more information about the technology itself. Where are they I have been familiar that some of these cloned animals, or animals they've tried to do some of these techniques with they don't survive very well or they're not able to be viable? And so I'd be interested in maybe having more data about what—both what the state of the art of the technology is and what some of the different challenges have been to bringing these things to life."*

5. **Stakeholders other than the Public:** Identification of persons and organizations who are, or will be, influenced by synthetic biological technology; also includes shareholders who have some voice in the development and use of synthetic biological technology. "*Who regulates robots? Like the—I don't know this question. Like I can imagine a scenario where this becomes like a DARPA project, and then the regulation becomes more complicated. I can also imagine a scenario where this is like a, you know, an environmental issue, so again EPA would be involved. But I—I without knowing what it's for, I don't know."*

6. **Values and Ethics Considerations:** Statements associated with the relative worth, merit, or importance of the synthetic biological technology and its influences; also considers the "rightness or wrongness" associated with synthetic biological technology and its influences. *"I could see something like the society—different members of society really*

wanting much more oversight potentially. And I can see maybe this really getting into triggering concerns about like Franken-organisms, you know, Frankenstein-ish kind of organisms or creating artificial life, those kinds of debates and people who really get ignited around that kind of thing."

7. **Premarket—Postmarket Data Collection:** Identify data collection efforts or data needs as they are portrayed either premarket or after the synthetic biological technology has been disseminated for commercial or consumer use.
8. **Experts only—inclusive voices:** In-group-Outgroup defining statements that are either inclusive or exclusive of outsiders to expert groups
9. **Economic Factors:** Identification of how financial issues impact synthetic biological technology development and vice versa. "*Those would be important and—and again it gets into these—there, you know, it goes beyond just—in all these cases I think it goes beyond just pure safety issues although I think that's a big one. But all these other kinds of economics, and who benefits from the technology, are people in developing countries being exploited through these techniques and these technologies? There's this whole other can of worms that kind of comes out with these technologies that I think would mean research and engagement that you really start talking about, you know, who is benefiting and the bigger kind of picture issues that sometimes you get set aside with the focus on just human risk"*.
10. **Anticipated Risks-- Social/Societal:** Identifiable risks for society due to the synthetic biological technology. "*I think we have a really—like agriculture and food are big issues in the broader societal and governance context. And so these—any engineering having to*

do with—with agriculture, I think, are going to be a big deal and have potentially huge positive and negative impacts. So they are very important.”

11. **Anticipated benefits—Social/Societal:** Identifiable benefits for society due to the synthetic biological technology. *“Anything that helps us save energy and use, you know, less harsh chemicals is a good thing. So, in the broader societal context, I don’t think it would be a huge difference, but it’s something that, you know, it will be welcome nonetheless. And it’s kind of like, if you go from an energy-expensive computer to an energy-cheap computer or something that uses low power, it’s always a good thing. But you don’t necessarily see a huge drop in your energy bills; it’s like that.”*

Appendix B: Synopses of Case Studies

1) Biomining:

Biomining is the generic term that describes the processing of metal-containing ores using biological technology. Researchers are evaluating this field to diminish the monetary, environmental, and human health hazards associated with precious metal mining. Biomining involving bacteria and other microorganisms is currently employed in mines worldwide, including Australia, Chile, Ghana, South Africa, and parts of Central Asia. Reports suggest that the industrial adoption of this technique will likely continue to increase globally. Biomining entails two distinct processes: bio-oxidation and bioleaching. Bio oxidation is the use of microorganisms to oxidize the mineral matrix in which the target metal is entrapped, thereby opening the structure of the mineral so that it is more easily penetrated by a chemical that will mobilize the target metal. This enriches metals by mobilization and removes metal sulfides from ores that contain precious metals. Bioleaching is the solubilization of metals, most prominently copper, cobalt, nickel, zinc, and uranium. The technique employs manufactured acidophilic bacteria to oxidize metal sulfides. In this process, crushed ore is sprayed with sulfuric acid, stimulating the growth of manufactured acidophilic bacteria. These bacteria oxidize insoluble metal sulfides like those of copper, nickel, cobalt, and zinc and convert them to soluble metal sulfates. The liquid products of dissolved metals drain to the bottom of the ore heap and may then be subjected to electrolytic processing and converted to pure, solid form.

2) Cyberplasm:

Cyberplasm" is the term dubbed by researchers funded jointly by the National Science Foundation (NSF) and the UK's Engineering and Physical Sciences Research Council (EPSRC) that describes the convergence of synthetic biology, biomimicry, nanotechnology, and robotics to construct a micro-scale robot designed to be capable of sensing and treating pathogens within plants and animals or for other functions involving sensing and remediation (e.g., environmental chemicals). Cyberplasm is a bio-hybrid that integrates engineered bacteria, yeast, and mammalian cells to undertake device-like functions modeled after the sea lamprey. The sea lamprey serves as the model organism to create Cyberplasm as it swims and has a primitive nervous system that is relatively easy to mimic. Biomimetic, synthetic muscles are designed to initiate undulatory movement and propel the robot through the water, while synthetic sensors derived from yeast cells report environmental signals. Visual receptors couple the electronics for sensation and actuation through light signals. This combination serves as a primary electronic nervous system. The "electronic brain" signals muscle cells to move. For example, mammalian muscle cells could be used as actuators engineered to have the minimal cellular machinery required for excitation and contraction and are coupled with rhodopin to respond to light. These cells are fueled by microbial cells that produce glucose from environmental chemicals. The muscle cells use the glucose and convert it to ATP in the mitochondria, combining power generation with actuation. Hydrogel is the filler is the material that moves as plasm.

3) De-extinction:

While some synthetic biology projects aim to create new life, others attempt to bring life back to how it was before human involvement. One such technology, "de-extinction," is taking shape through the convergence of disciplines, including synthetic biology, cloning, genetic engineering, and stem cell research. Put simply, de-extinction will recreate endangered and extinct species. Stewart Brand, editor of the Whole Earth Catalog, describes the exigence of the de-extinction plan, noting that "[h] humans have made a huge hole in nature in the last 10,000 years…[and] we have the ability now, and maybe the moral obligation, to repair some of the damage." The plan of de-extinction technology is two-fold: First, to catalog the genomes of a great host of species around the world, and second, to help restore organisms and habitats damaged or destroyed by human activity. Projects like Genome 10K aim to assemble a genomic zoo—a collection of DNA sequences representing the genomes of 10,000 vertebrate species, approximately one for each vertebrate genus. The project is making use of a variety of technologies, including DNA extraction, amplification and sequencing, phylogenetic and population genetic analysis, and bioinformatics approaches to whole-genome analysis to record such genetic diversity with the hope that the catalog will serve as an unprecedented resource for the life sciences and worldwide conservation efforts.

4) Plant Microbes:

Increasing world populations lead to a greater need for new and improved food crops. The challenge is how to meet these needs in an environmentally sustainable way. Some experts and technologists are turning to microorganisms as a possible avenue for improving large-scale agriculture. A wide diversity of microorganisms colonize plants. Thousands of microbes can be found living on the stems, leaves, and roots of most plants, and they can also be found within plants' intercellular spaces. These microorganisms can profoundly affect food crops as microbe interactions can either benefit or harm plants depending on the encounter. For instance, densely colonized soil contains beneficial fungi and rhizobia, which are symbiotically associated with roots and provide plants with mineral nutrients and fixed nitrogen in exchange for carbon. By contrast, plants are constantly exposed to various fungal, bacterial, and viral pathogens, as well as harsh environmental conditions, and have evolved unique defense mechanisms to fight these infections and events. Some experts and technologists propose to employ techniques from the field of synthetic biology to catalog and engineer microorganisms with desired characteristics. The proposed engineered microorganisms are designed to manifest various outcomes in food production, including improved plant growth, yield, and efficacy, as well as protection from multiple plant pathogens and environmental conditions. Developers of the engineered microorganisms claim that their products will be more environmentally friendly than traditional chemical fertilizers and pesticides and that the engineered microorganisms will also reduce the need for soil fertilizers. Current projects focus on corn and wheat applications, representing multi-billion-dollar markets worldwide.

Appendix C: The Delphi method

Delphi methodology is ideal for small expert populations to allow the participants to state their opinions anonymously without fear of repercussion. Experts participate in the Delphi study on an individual level as well as within their time frames according to each round. The Delphi method is designed to procedurally blend polling and conferencing by avoiding direct expert communication. This technique forces delays where experts have time to reflect on the study's issues while granting the study's administrators the ability to facilitate the "equal flow of information" to and from all participants as required by the survey (Linstone, 1975, p. 11). An argument for the benefits of this forced delay is that a curbed psychological effect occurs for the study participants, and it tends to require less time for observers partaking in the Delphi. This type of methodology assists in maintaining the group dynamics conducive to distilling responses and building toward group consensus. The Delphi method is utilized "when accurate information is unavailable or expensive to obtain, or evaluation models require subjective inputs to the point where they become the dominating parameters" (Linstone & Turoff, 1975). The Delphi method provides an iterative process that calibrates opinions and builds toward consensus through multiple rounds. In a Delphi policy, consensus does not necessarily need to be the endpoint; instead, revealing views and options could be the ultimate goal (Turoff 2002). The goal for this Delphi study was the latter.

Appendix D: Upstream Oversight Assessment

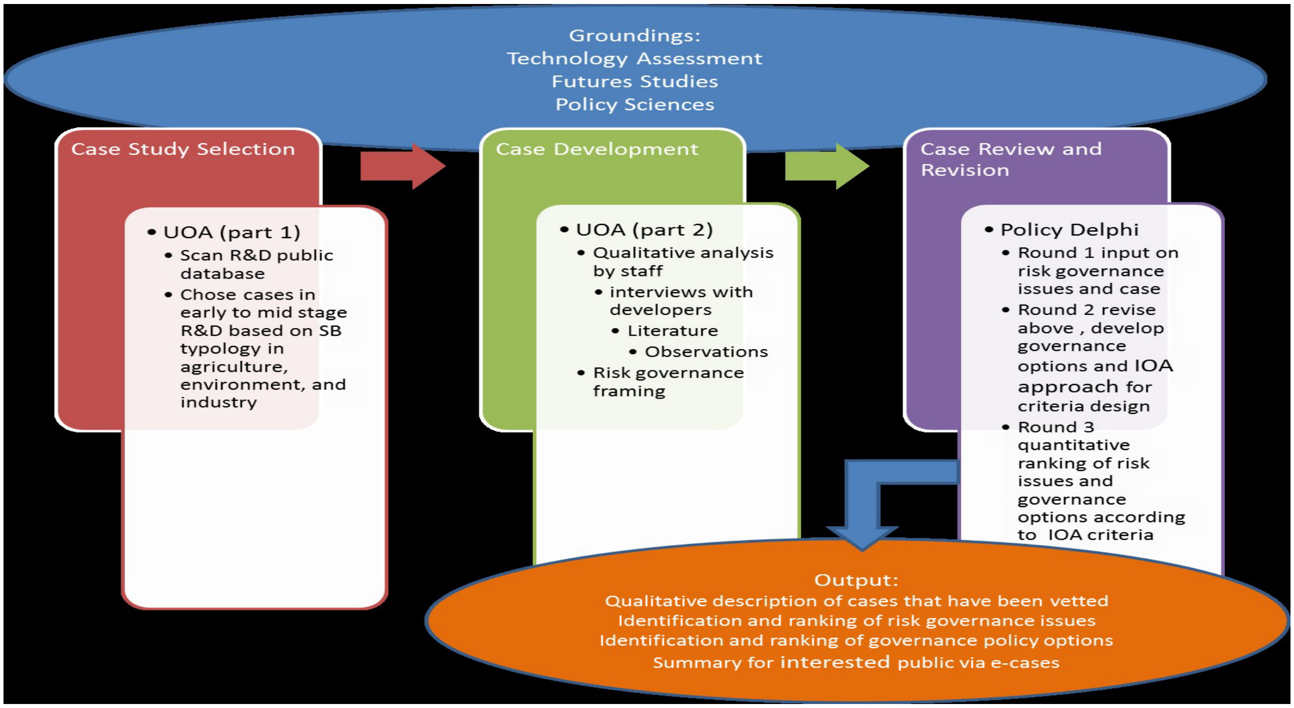

Figure 2: Upstream Oversight Assessment.

Paper 2: When Expert Opinion Meets the Public, Part 2:

Expert Opinion Differences Between Synthetic Biological Applications

& Among Expert Affiliations.

ABSTRACT

Following a Policy Delphi protocol, this paper first explores experts' attitudes and opinions on the role of the public concerning the development and use of four specific synthetic biology applications currently being researched and developed: biomining, cyberplasm, de-extinction, and plant microbes for nitrogen-fixation. Second, this research explores whether and how experts' attitudes vary by affiliation and synthetic biology applications. Data were collected from the 1st and 2nd rounds of a more extensive four-round Policy Delphi longitudinal study that included structured interviews with synthetic biology experts, a quantitative survey, a face-to-face workshop, and a final shorter survey. Delphi studies like this one provide iterative processes that calibrate and reveal opinions through multiple rounds of data collection. This paper leverages crosstab analysis to compare expert opinions by cases and expert groups that emerge from several rounds of the Policy Delphi study.

Introduction: History of the Relationship between Experts, the Public and Science Policy

The relationship between experts and the public has been long studied and is often a point of contention when applied to the public's influence on public policy. Experts have usually held the dominating decision-making power and influence in science and technology policy over public opinion and engagement, which has not often been a significant factor in the policy development of emerging technologies. Scholars have identified why experts care about the public's attitudes toward emerging technology. One of these reasons is increased expert accountability within the public sphere. Science could arguably be viewed "as increasingly more embedded in, and hence more accountable to, society at large" (Jasanoff, 2003; Gibbons, Limoges, Nowotny, Schwartzman, Scott, & Trow, 1994). Another reason is normativity, a feeling that experts and experts should care about the public's attitudes concerning emerging technology. Powell & Colin (2008) stated that there is a "growing awareness that citizens should have some say in decisions about [scientific and technological] developments" (pg. 127). Improved decision-making is another reason experts care about the public's attitudes toward scientific development and emerging technology. Rowe and Frewer (2000) state that "there appears to be increasing realization in governmental, scientific, and industrial bodies that they need to pay greater heed to the public, become more accountable and responsive to it, and involve it in policy decision making when feasible" (pg. 4).

Some scholarly schools of thought about the public's participation in the development of science and technology, and subsequently, science and technology policy, contend that the public should be led by those who have the necessary knowledge (deficit model) and technical skills (technocracy) needed to make such policy. Walter Lippmann's book Public Opinion (1922) exemplifies the deficit model view of the public and public opinion. Lippmann, a former journalist, stated that "most people [are] passive consumers of media images and information, with little real understanding of the complicated issues of the day" (Priest and Greenhalgh 2011, as stated in Lippmann 1922, pg. 1523). Conclusions from this end of the theoretical spectrum reason that "complex societies must be governed primarily by elites, rather than controlled by the opinions of the masses" (Priest and Greenhalgh 2011 as stated in Lippmann 1922, pg. 1523). In Lippmann's opinion on the theory, the information system should be used to persuade "the masses" that the policy decisions of the elite are correct. Sturgis & Allum (2004) discuss another assumption of the deficit model by stating that "lacking a proper understanding of the relevant facts, people fall back on mystical beliefs and irrational fears of the unknown" (pg. 57).

On the other hand, John Dewey, Lippman's rival, argued an opposing theory of public opinion in his books *The Public and its Problems* (1927) and *Human Nature and Conduct: An Introduction to Social Psychology* (1922). He viewed "democracy not merely as a means, but as an end in itself"—something he valued as ''a form of moral and spiritual association'' (Priest and Greenhalgh 2011, pg. 1522). Dewey stipulates "that participatory democracy creates the conditions for self-realization and introspection, as well as making public aware of their collective capabilities" (Priest and Greenhalgh 2011, pg. 1522). Dewey's theoretical argument of public opinion states that "people enhance their ability to interact within the greater public arena, as well as to reflect on and modify their personal behavior" through discussion of the issues at hand (Priest and Greenhalgh 2011, as stated in Dewey 1922). According to Dewey, "Communication allows the public to think more critically about issues and themselves, to be more thoughtful in their deliberations, and to be better problem-solvers, gaining the ability to control their behaviors and beliefs" (Priest and Greenhalgh 2011 as stated in Dewey 1922, pg. 1522). Priest and Greenhalgh (2011) highlighted the significance of this theory by saying that “this heightened human agency utilizing democracy allows people to learn from the past and to take charge of their future.

Deficit Model

The consistent debate over emerging technology and its products will likely continue as more technological advances are introduced into society (Costa-Font, Gil, and Trail, 2008). The main premises of this debate will continue to highlight the perceived benefits and risks, safety aspects of human use or consumption, ecological effects, and how these technologies are identified in the market. Traditional views or the “deficit model” stipulate that decision-making should be left in the hands of those who can understand the knowledge within natural or technical processes and who have the skills necessary to participate in the production of new knowledge within those technical systems, namely experts. (Rowe & Frewer 2000; Perhac 1996; Renn 1992). There is an underlying assumption that “if citizens better understand science and benefits, they will become less wary” of emerging technology, including but not limited to synthetic biology applications (Durant and Legge 2005, pg. 181). Support for the deficit model is found in earlier literature through idioms of suggestion, including phrases like “human inadequacies,” “the public’s capacity to understand,” “deficiencies in knowledge,” “reasoning abilities of the layperson,” “the public’s ignorance,” and “limitations due to attitudes, beliefs, and motivations.” Such thinking often discounts the concept of public engagement in the development and governance of scientific and technological advances as unnecessary and problematic (Sturgis & Allum 2004; Rowe & Frewer 2000).

Neo-Liberal Governance

Neo-liberal top-down governance has been described as general actions of governance or, in this case, specific public engagement practices facilitated by those traditionally expected to reduce or contribute to the knowledge and decisions around science and technology. This model promises to act as a bridge between the experts and institutions and decision-making surrounding science and technology. Critics of this model of public engagement state that "top-down facilitation of citizen engagement raises some difficult paradoxes" (Powell & Colin 2008, pg. 130). They challenge this model by examining if genuine and effective public engagement practices can be possible, especially since institutional support may be low as power-sharing by institutions and governmental agencies is needed to facilitate such activities. Critics also ask if "it realistic to expect highly constructed short-term "exercises" to have any impacts on decisions about scientific and technological research" (Powell & Colin 2008, pg. 129). These critics posit that these exercises may "help citizens gain group deliberation experience, they are unlikely to prepare them for "real-world" political participation, which is long term, seldom controlled or facilitated, and often contentious" (Powell & Colin 2008, pg. 129).

Participatory Democracy

Participatory democracy can be defined as a model that engages and includes public opinion on the development, governance, and utilization of science and technological advances at all stages of the process, especially the very early stages (Jasanoff 1997). More recently, public engagement models have attempted to be more inclusive of public opinion on the direction of science and technology (Rowe & Frewer, 2000). The deliberative models of participation in governance are partly supported by the counterarguments to the deficit model and neo-liberal top-down governance structural models of public engagement. Some of these counterpoints argue that the "knowledge of experts, who often disagree among themselves" (Rowe & Frewer 2000, pg. 5; Kraus, Malmfors, and Slovic 1992; Pollak 1996; Jasanoff 1997) also has limitations. Other counterpoints contend that the

> "the public is not necessarily irrational in its concerns about risks or in its environmental justification of experts' claims, given the abundant historical experience of episodes in which risk promoters have concealed or ignored relevant risk data or simply sought to advance their interests by using such data selectively" (Rowe & Frewer 2000, pg. 5; Jasanoff 1993; Leiss 1995; Petts 1997).

Further, "value [and ethical] judgments are made at all stages of the risk management process, such as in deciding which risks to evaluate." Hence, those decisions should be inclusive and reflect all interested and affected parties, namely the public. (Rowe & Frewer 2000, pg. 5; Levidow 1994; Kunreuther and Slovic 1996; McCallum and Santos 1997).

Priest and Greenhalgh (2011) state that the" present trend toward encouraging public engagement in discussions about science and technology policy has more in common with [participatory models] than [deficit or top-down models]" (pg. 1523). Some scholars have advocated for a model that can interact effectively amongst various "contextual and environmental factors" (Rowe & Frewer 2000, pg. 11). It can be argued that, at best, "the intrinsic features of any participation method will not act alone, while one method may be appropriate in a certain situation, another method may be more apt under different circumstances" (Rowe & Frewer, pg. 25).

Contemporary scholars contend that "lay citizens have valuable knowledge and perspectives to bring to discussions about technological developments, and their input can contribute to more comprehensive and robust societal decisions about these developments" (Powell & Colin, 2008, pg. 131; Fischer, 2000; Goven, 2003; Kleinman, 2000). Other scholars state that "science that draws strength from its socially detached position is too frail to meet the pressures placed upon it by contemporary societies. Instead, they imagine knowledge that would gain robustness from their embeddedness in society (Powell & Colin, 2008, Pg. 133)." If experts expected and demanded that the public have significant input in the decision-making process within emerging science and technology, would the current environmental injustices remain so?

There are also counterexamples. Experts ' attitudes are widely disparaged in specific subject areas, such as global warming and vaccination policy. These expert attitudes reflect that too much public participation of the wrong type could be detrimental. They contend that insulating scientific developments from politics is good. At the same time, experts must maintain that increasing public influence is also good. Part of the issue is reconciling these attitudes while creating public participation channels that powerful interests of non-scientific political motives will manipulate. These quotes have been pulled from the data gathered in the study concerning participatory governance. The following quotes from the expert panel summarize the challenges of participatory governance structures:

> *"We think that one of the ethical issues is that the public should have full information on these technologies' health and safety impacts. We think workers should have full information on it, and local communities should be able to regulate what's happening in their community just as states and the federal government can."*
>
> *"…of what we value and ensuring a full and fair discussion on why—why we should be doing this. And again, I mentioned early on that there could be some excellent reasons to do it, you know, it speaks to us—to responsibility and ethics, but it also speaks to the sort of trade-offs. And I think oversight in the development and implementation of this technology should be aired fully, you know."*
>
> *"You have people now, the IGEM folks who are, you know, high school, college-age students up to working professional experts who can access and use some of these*

technologies, tools, and methods. And I think that also poses problems for governance where I think in the past governance has been thought about, you can isolate that to, let's say, an elite academic laboratory or maybe even an elite industrial laboratory, but you didn't maybe always have to think about the technology filtering down to the more working level, or the student level."

Research Questions

In order to determine where experts fall on the spectrum of governance, it is important to identify their root attitudes towards public participation. In this part of the study, the goal is to compare expert opinion and attitudes by case and affiliation.

1. Do expert groups differ by affiliation in their beliefs about the role of the public with regard to synthetic biology?

2: What are the differences in expert discussion on public attitudes with regard to synthetic biology applications?

3. Do experts believe that the role of the public should differ based on the synthetic biology of the application being developed?

Methodology

The work reported here is situated within a larger project funded by the Alfred P. Sloan Foundation (PIs Kuzma and Cummings, Looking Forward to Synthetic Biology Governance: Convergent Research Cases to Promote Policy-Making and Dialogue [#556583]). The team employed a multi-stage policy Delphi method to facilitate data and information collection using a multidisciplinary expert panel. This Delphi method is a powerful source of grounded theory in that "it is inductively generated from fieldwork" (Palinkas, et. al., 2015, pg. 234; Patton, 2002, pg. 40). Grounded theory "emerges from the researchers' observations and interviews out in the real world rather than in a laboratory…" (Patton, 2002, pg. 40). Methods of future studies and policy sciences were used to develop and examine cases of synthetic biology (SB) in the context of risk policy and governance (Bell 2004; Bevir 2009). In particular, the Upstream Oversight Assessment was used to help select cases, develop initial drafts of the case studies, and construct questions to inform risk analysis and oversight policy (Kuzma, Romanchek, and Kokotovich 2008). The policy-Delphi process (Turoff 1970) was used to refine the case studies and elicit expert-stakeholder opinions (SMEs) about the potential risks, benefits, and ethical, legal, and societal (ELSI) issues associated with synthetic biological cases. The Delphi consisted of four rounds: a semi-structured interview, a quantitative survey, a face-to-face workshop, and a final shorter survey. The data used in this paper is primarily from the first round of interviews supported by quantitative data from the second round of the longitudinal Delphi process. The research focuses on thematic patterns found in specific sections of the initially coded interviews that relate in some way to public engagement and are analyzed for each case and expert grouping (Cummings & Kuzma 2017).

Case study selection

First, the team identified and selected ten diverse case studies of emerging synthetic biological applications by reviewing widespread media reports on synthetic biology research, cases that were subjects of other policy conversations, and the peer-reviewed and gray literature. Ten potential case studies were developed (A 2-page case study was vetted for accuracy by a set of synthetic biological experts who were not participants in this study). These synthetic biologists and policy scholars reviewed and commented about those that would best 1) cover a range of environmental release applications, 2) represent a range of synthetic biological technologies from highly engineered organisms to completely synthetic machines, and 3) show plausible cases that were being researched in labs at early or mid-stages or in other words, if successful would be deployed in 10 to 50 years (Cummings & Kuzma 2017). The resulting final four case studies throughout the policy Delphi project were utilized: biomining using highly engineered microbes in situ, cyberplasm for environmental detection, de-extinction of the passenger pigeon, and engineered plant microbes to fix nitrogen on non-legumes.

A case study analysis approach guided by upstream oversight assessment and anticipatory governance was used to guide question formulation for the interview and survey protocols that would be used to analyze risk analysis and oversight policy issues (Kuzma, Romanchek, Kokotovich, 2008; Yin, 2002). Kuzma et al. (2008, Pg. 1081) stated that the goal of upstream oversight assessment is to "identify data, risk assessment, regulatory policy, and engagement needs for overseeing these products so they can be addressed before market entry… has potential as a key element of anticipatory governance". This study uses distinct case studies of proposed and "in research and development" applications of synthetic biology to highlight areas that can be utilized to develop a model of public participation, a method that was called for in the upstream oversight assessment. (See Appendix B: Synopsis of Case Studies)

The expert sample

The sampling of experts was done purposively to attain information on risk, governance, and policy issues of synthetic biology applications. These sampled experts represent "information rich" cases (Palinkas, et. al., 2015, pg. 234; Patton, 2002, pg. 40) to provide some insight into the emerging ethical and social aspects manifested by the governance of the next generation of applications in synthetic biology (the previous 4 case studies as mentioned above). It was essential to draw from a range of expertise to cover multiple considerations for public engagement views and acknowledge the values and assumptions in risk analysis. The sampling of experts aimed to get similar numbers of representatives from different types of organizational affiliations and disciplinary perspectives.

The expert-stakeholder list was compiled using a mixture of web database searches and literature reviews for pertinent author names. Using basic Google database search techniques, the project team found several resources that yielded the names of experts and analysts associated with synthetic biology. Upon reading material related to synthetic biology (peer-reviewed journal papers, synthetic biology conference speaker lists, industry websites, etc.), the project team could categorize the expert stakeholders into six units according to the originating information. The initial set of experts contained 234 persons originating from the following groups: editorial review boards for critical journals like *Biotech and Bioeng,* Gordon Research Conference on Synthetic Biology speakers, BioBricks Foundation Synthetic Biological 6.0 meeting, SynBioBeta Conference speaker list (n=7), Georgia Tech Frontiers in Systems and Synthetic Biology conference list, National Science Foundation and Department of Energy synthetic biology policy workshop lists, President's Commission on the Ethics of Synthetic Biology, and other sources (e.g. recommendations made directly to project staff).

The project team recruited the stakeholders to gain expertise and affiliation. Affiliations included academe, industry, government, non-governmental organizations, and others (e.g., think tanks). The final subject matter expert (SME) group, according to self-reported disciplinary perspectives, was comprised of chemists, molecular biologists, engineers, sociologists, toxicologists, environmental experts, lawyers, Science, Technology, and Society (STS) scholars, philosophers, and policy practitioners or scholars, and others. Forty-eight members completed the survey used for the cross-reference between the qualitative data collected during the interviews and the quantitative data from the first survey. Four primary groups of experts by discipline were formed for analysis based on similar methods of inquiry: 1) Biochemical/Molecular Biology/Chemistry, 2) STS/Sociology/Philosophy/Ethics, 3) Ecology/Environmental Science/Toxicology, and 4) Policy/Law. Some experts identified with more than one disciplinary group (Figure 1). Results for the expert group of ecology, environmental science, and toxicology have been scaled to account for the disproportionate amount of experts in that disciplinary group as compared to the other three groups (all other expert groups had 2.3 times more expert participants than the group whose participants identified in the disciplines of ecology, environmental science, toxicology).

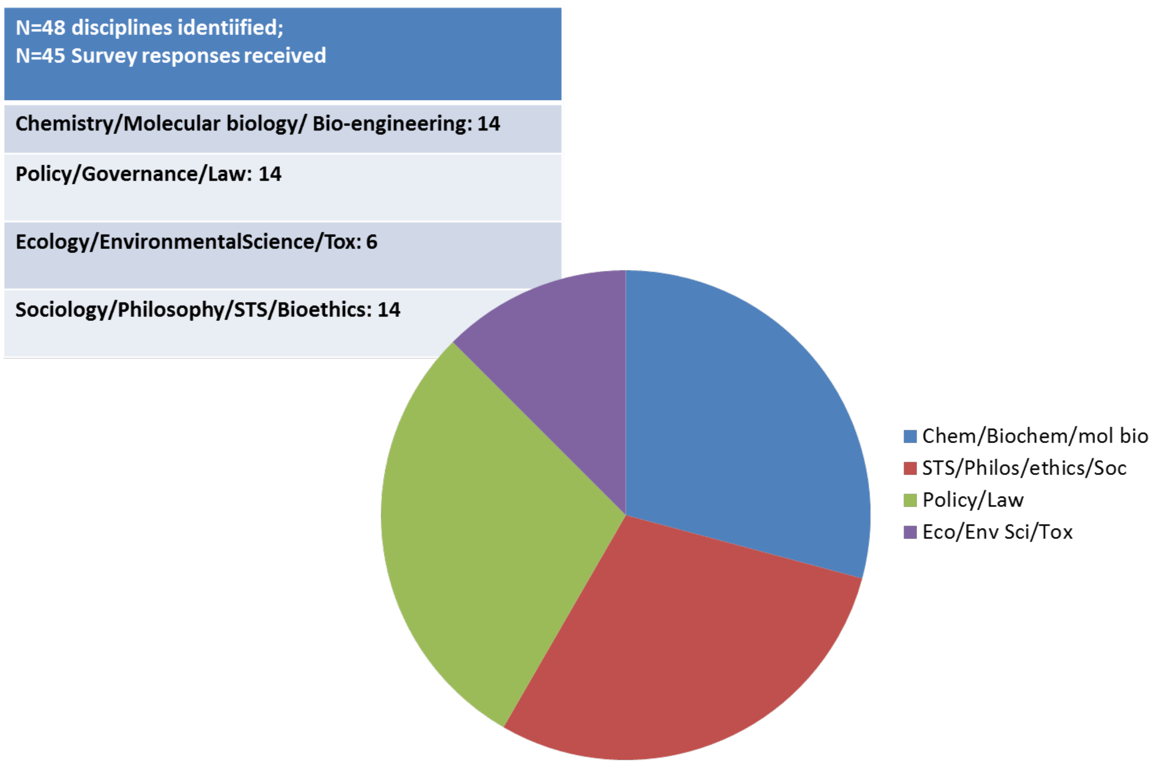

Figure 1: Expert Affiliations.

Semi-structured interviews

In practice, most Delphi exercises try to maintain a three- or four-round limit by utilizing the following procedures: (1) the monitor team devoting a considerable amount of time to carefully pre-formulating the apparent issues; (2) seeding the list with an initial range of options but allowing for the respondents to add to the lists; and (3) asking for positions on an item and underlying assumptions in the first round. Our Delphi consisted of four rounds: a semi-structured interview, a quantitative survey, a face-to-face workshop, and a final shorter survey. This paper essentially uses data from round one (with support from round two, the first survey built upon the semi-structured interviews to formulate questions of risk analysis and governance).

Survey

The quantitative survey method used included questions about potential risks, benefits, and ethical, legal, and societal (ELSI) issues associated with synthetic biological cases. The second round of the Delphi study consisted of a survey with closed- and open-ended questions based on initial themes that emerged from the interviews.

To prepare for the rounds of the Delphi study, the participants were asked to read four case studies about synthetic biology applications. Kuzma and Tanji (2010) outlined a case study selection process and approach in a previous examination of detrimental governance profiles built upon in this study. Kuzma and Tanji (2010) state that "different categories of synthetic biology applications may warrant different oversight regimes, and there might not be an appropriate 'one size fits all' approach." They argued "that policy recommendations should be built from consultation with experts and stakeholders of multiple disciplines, and developed in the presence of stakeholders and public citizens" (p. 94). The importance of this project is that it uses the policy Delphi rubric by way of case studies to meet the call for a more robust policy analytical approach to various synthetic application fields (Cummings & Kuzma 2017).

Data from experts who participated in the Delphi study were obtained through phone interviews, surveys, and in-person interactions conducted by researchers on the Delphi Study team.

The interviews posed questions on general governance and risk analysis needs for synthetic biology and the four specific case studies. The second round of the Delphi study consisted of a closed and open-ended survey based on initial themes that emerged from the interviews (Ndoh, C., Cummings, C.L., Kuzma, J., 2020). Following the survey completion, study participants were invited to a two-day workshop where small and large group discussions and activities were conducted to further determine opinions of risk assessment and governance needs for synthetic biology. Twenty-nine of the study participants attended the two-day workshop. During the workshop, participants completed mind-mapping and concept-mapping exercises in small groups and listed challenges and opportunities for synthetic biology governance as a large group. They completed a second survey and had extensive group discussions. As the last part of the Delphi, participants were given a post-workshop survey to complete.

Coding and Recoding

Transcribed interview data was then imported into Nvivo software for coding using cross-tab analysis. Iterative thematic coding was employed to review the transcribed data and find consistent themes discussed by the experts. From these, many subthemes emerged around expert opinions of risk analysis and governance needs for the 4 cases selected. The project team initially coded the interview data using Nvivo 10 to explore and identify thematic patterns, of which 53 were created and coded. A sub-sample of eleven thematic patterns was identified based on their intrinsic relationship with the public. These 11 thematic patterns were then explored for deeper thematic patterns using the crosstab analysis process, and 13 new thematic patterns emerged concerning public engagement and opinion concepts.

These 11 thematic patterns have an implicit relationship with the public engagement process. The subsample of 11 thematic patterns identified in the first wave of coding of the expert interviews included the experts' opinion on *public engagement, public perception, responsibility for governance, access to information, stakeholders other than the public; values and ethics considerations, premarket-post market data collection; experts only-inclusive voices; economic factors; anticipated societal risks; and anticipated societal benefits.* (See Appendix A-Sub-sample of 11 of the 53 original thematic patterns).

From these methods, 13 thematic patterns were identified, as seen below:

Table 1: Thematic Patterns (as developed in Paper 1).

New Thematic pattern	DEFINITION
Information Sharing	Statements related to sharing information and being open with information with different stakeholders.
Transparency	Statements that inquire about how all information is included and how information is disseminated. How open are officials/stakeholders to the public?
Apparency	Statements concerning the intentions if intentions and meanings are exposed and readily accessible to the public.
Education	Statements about whether the public is/should be educated about science and emerging technology and its applications.
Outreach	Statements about whether outreach efforts to the public are essential to developing and utilizing emerging technology.
Knowledge	Statements about what society knows, What society needs to know. How important is it?
Equity	Statements concerning how benefits, costs, unintended consequences, etc., are distributed over different communities.
Social Contracts of Experts	Statements describing the expectations of/to the public of experts that are developing these technologies.

Table 1: (continued).

Control of Technology	**Statements refer to whether or not the public has control and influence over when, where, and how the emerging technology is used. If not, who does? Why? If so, what are the social implications?**
Acceptance	Statements about the public's concerns regarding the utilization of emerging technology, whether the public has or will accept technology.
Comparisons to other Countries	Statements that reference another country's structural, cultural, operational, and governance framework about emerging technology.
Similarities to Genetically Modified Foods	Statements that reference genetically modified food/agriculture as a framework/model for other emerging technology.
Economics	Statements that elicit economic inferences with regard to emerging technology and how those inferences influence decisions.

Those 13 thematic patterns were examined using cross tab analysis in order to generate similarities and/or differences between the groups and between cases. Different attitudes of public engagement regarding emerging synthetic biology applications did occur and could be identified by affiliation, although the results were not as conclusive or divergent as originally thought. Experts from all four affiliations view governance of emerging technology as inclusive of some aspect of the public.

Discussion

As in an exploratory analysis, this discussion will include parts of the transcript of the actual interviews with the expert to highlight the underlying theme (Swedberg, 2020). Quotes from each of the expert affiliations assist in illuminating this convergence throughout the analysis, as shown in Table 2. Table 2 displays quotes stated by each expert's affiliations, as seen below:

Table 2: Examples of Quotes by Expert Affiliations.

Chemical **Biochemical** **Molecular Biology** **Engineering**	*"It's easy to look at the general public and talk about how badly they might sensationalize some area to its detriment."*
Policy **Law**	*"I think it's a problem of why research needs to be driven by attention to the needs of the poor, and not just attention to the technology and not just attention…Here, the public seems to have no say in the kind of technology that's being developed."*
Science/Technology & Society **Philosophy** **Ethics**	*"So I could see that people would look at this and say, I don't want those NANO robots in me. What if your child had a brain tumor, and this could get rid of your kid's brain tumor...You would feel very differently about that technology."*
Ecologist **Environmental Science** **Toxicology**	*"How do we help the public understand what the real risks are as opposed to the perceived risks? How do we educate the investment community to understand what the societal acceptance issues will be…?"*

Table 3: Total Number of Codes by Expert Affiliation.

Expert Affiliation	Number of Comments
Biochemical/Molecular Biology/Chemistry	305
Policy/Law	410
Ecology/Environmental Science/Toxicology	153 (unscaled)/ 352 (Scaled)
STS/Sociology/Philosophy/Ethics	402
	Total: 1270 comments coded in NVivo

Expert Group by Group

Figure 2 shows the number of times each thematic pattern was discussed by each kind of expert affiliation. Experts who study issues in science/technology and society, sociology, ethics, and philosophy discussed issues surrounding public acceptance and apparency, made comparisons to other countries, and discussed issues surrounding genetically modified foods more than any other expert affiliation. Experts who study or work in policy or law discussed the concepts of economics, public education, information sharing, knowledge production, the social contract of experts, transparency, and equity more than any other group. This means that this expert group led, as a pattern, 8 out of 13 of the thematic patterns in the discussion. However, it is notable that some of these results are comparable between the expert groups. For instance, issues of transparency were discussed by policy/law experts, chemical/bioengineering experts, and social scientist experts 12 times. Control of technology issues was discussed by policy/law experts, chemical/bioengineering experts, and social scientists experts between 18-21 times. Equity issues were discussed 50 times by policy and law experts and 53 times by social scientist experts. Information sharing was discussed by policy and law experts and social scientist experts 39 times and 38 times, respectively. All expert affiliations discussed outreach efforts between 4-

6 times. Three of the expert groups discussed issues surrounding transparency 16-18 times. Economics was the issue mentioned or discussed the most.

As for research question 1, experts who identified as social experts or policy experts did discuss public engagement concepts at a higher rate than natural experts, but this is relative as experts who identified with the Biochemical/Molecular Biology/Chemistry expert group discussed these concepts more frequently than their natural science counterparts. On average, all four affiliations spoke most often about the public when discussing economics and public acceptance, as shown in Figure 2. Experts who identified as ecologists or environmental experts have not discussed public engagement constructs or themes as much as any of the other expert affiliations by far. In 11 out of 13 of the thematic patterns, experts in ecology or environmental science discussed these concepts the least as compared to their counterparts. The raw number was multiplied by the ratio of 2.3 (ratio compared to the number of participants in each affiliation (14 for each except ecology/environmental science, which was 6 participants). This does not mean that the social experts were at the forefront of every thematic pattern. In only 4 of the thematic patterns did experts who identified as social experts lead in the discussion of these issues, as shown in Figure 2, although this expert group ranks 2nd, as shown in Table 1. Also, public engagement concepts of economics (180) and public acceptance (243) were discussed the most across all of the affiliations, as shown in Figure 2 below:

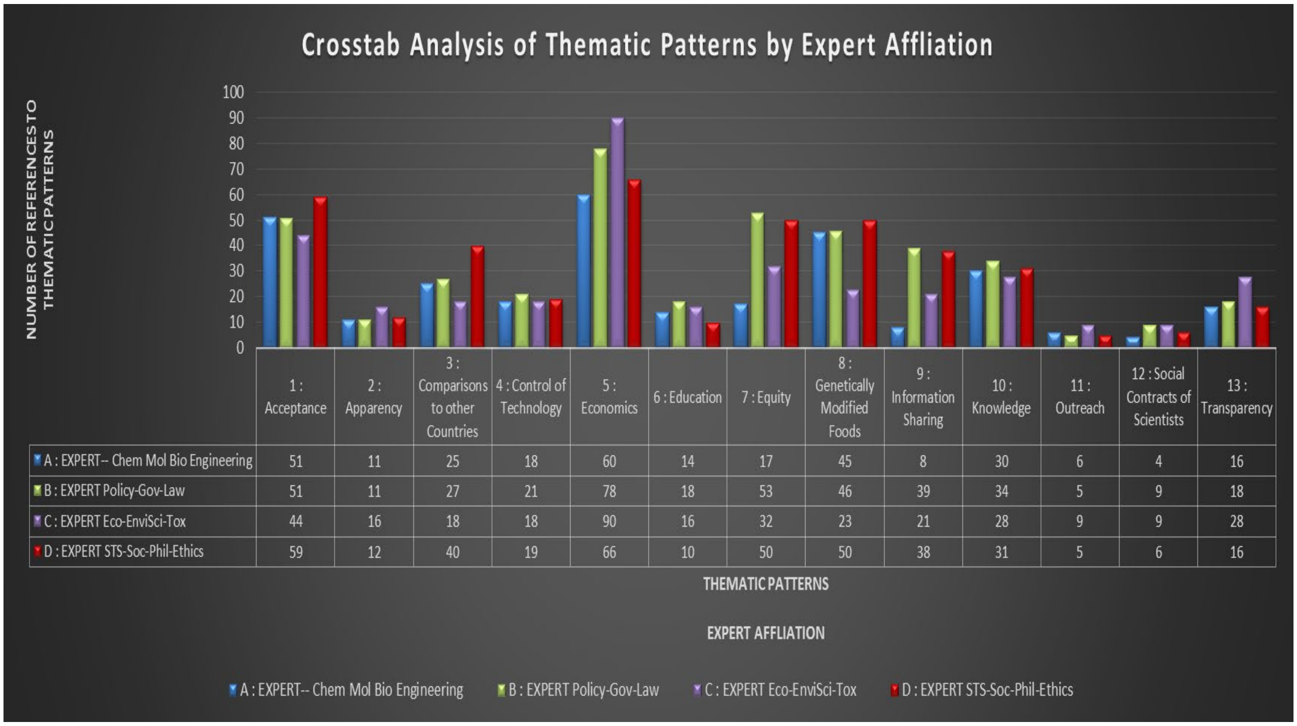

Figure 2: Crosstab Analysis of Thematic Patterns by Expert Affiliation.

Biochemical/Molecular Biology/Chemistry

The most prominent concern discussed by this group included the economics surrounding the development and distribution of the technology (60x), followed by the public's acceptance of the technology (51x), with genetically modified foods coming in third (45x). The biochemical/ molecular biology/chemistry group (as natural experts) called for immediate public engagement in bio-mining to assess uncertainty. Development of engineered strains that produce harmful organic matter, especially if these strains carry components that are detachable, may intensify the disruption of the "ecological balance in unforeseen ways" and contribute to the uncertainty (Li, Zhao, Zheng, & An, 2021, pg. 4). Uncertain hazards also lie within the distribution of these synthetic biological elements through "inhalation or contact ingestion caused by applying these substances to insecticides or sprays such as off-target effects of active ingredient concentration or gene silencing" (Li, et. al. 2021, pg. 4). Heinemann & Walker (2019) and Li, et. al. (2021)

discuss how “biologically active substances and vectors” may not fit in the current risk assessments models and regulatory audits as “they are often excluded from the hazardous chemical category and are explicitly excluded from the category of genetically modified agents (pg. 4).” This emerging loophole in oversight may contribute to “dual-use allocations (pg. 4)” or negative externalities in the environment or to overall human health. Li, et. al. (2021) go one to state that “as we cannot get an affirmative answer on the question whether all possible genetically modified foods are safe, we could not foresee what it would bring about if artificial life was released in nature” (Li, et. al. 2021, pg. 4; Heinemann & Walker, 2019). All four of the synthetic biological cases have these elements of uncertainty. These statement discuss the public’s acceptance in regards to bio-mining:

> *“So only after we develop those plausible scenarios, then we can have some kind of a deliberation or deliberative exercise involving the public, and that will be one way of gauging the risks in terms of how it would be perceived, whether this will be desirable social outcomes or not desirable social outcomes, whether the perception of harm outweighs the expectations of the benefits. So this should require a lot more foresight, scenario development, and public engagement in terms of assessing uncertainty.”*

By contrast, on cyberplasm, these experts take another route as they favor using a citizen jury, an outreach and educational opportunity, to increase understanding before public engagement is accepted.

> *“But there’s a technique that is used in the environmental areas every now and then called citizen juries, and that’s—and then they’re a group of just normal citizens is brought in to weigh in on a big decision related to a forest or something like that. And they’re not necessarily knowledgeable about the area, but some time is spent in educating*

them about the issue they're facing, and a lot of time is spent facilitating discussions. And then—and then the jury comes up with, say, a jury decision on whether this is something that that they believe should—people should go ahead with."

The biochemical/molecular biology/chemistry group may be more precautious about de-extinction due to its novelty and potential irreversibility (Cummings and Kuzma 2017; Ndoh, et al. 2020), as well as the moral hazard of forgoing other climate or ecosystem protection actions. This statement discusses the equity issues surrounding de-extinction in the context of economics:

"that might happen, so there would be a lot of costs to who knows, the taxpayer, the society as such to evaluate these technologies, and then that's why the so-called, what's more, important to evaluate the safety of this technology or not do it at all and just carry on with what we have and move that money for other emergency like tackling climate change for example that would be a relative side. Spending too much time and effort and money on this that is not that essential."

In genetically modified food, this group takes a technologically optimistic view of engineered plant microbes. This statement is in regard to genetically modified foods with plant microbes:

"*But with engineered plant microorganisms, we're talking about improving food production while decreasing contamination and pollution of the environment with chemicals. And the ability to have microbes help plants grow in more marginal dirt, and if they are able to use more marginal water, the impact on health, humans, and the environment would be hugely positive."*

Recently, Bauer-Panskus, Miyazaki, Kawall, & Then (2020) summarized the new challenges that arise in risk assessment "when genetically engineered plants can persist and propagate in the environment as well as produce viable offspring" and highlighted that "next-generation effects may be influenced by heterogeneous genetic backgrounds that may trigger unexpected effects in interaction with environmental conditions" (Li, et. al. 2021; pg. 4; Bauer-Panskus, et. al., 2020). The study goes on to point out that the biological characteristics of the original engineered plant may not be adequate to forsee the possible hazards of the next generation. Some of these issues include "exacerbation of weed problems, displacement, and even extinction of native plant species, emerging from spontaneous propagation and gene flow, resulting in a reasonable concern that might escape environmental risk assessment" (Li, et. al. 2021, pg. 8; Bauer-Panskus, et. al, 2020). The study states that the risk assessment of synthetic biological organisms capable of "persistent and spontaneous propagation in the environment is highly spatiotemporally complex, causing many uncertainties" (Li, et. al. 2021, pg. 8; Bauer-Panskus, et. al., 2020).

The biochemical/molecular biology/chemistry group here displays examples of anti-deficit thinking among a group that often takes on a deficit model. Experts agreed under the thematic pattern of the social contract of an expert about "reassuring the public the technology is safe" but did not agree on the specific levels within this reassurance such as safe for who, safe for how long, and the parameters of the definition of acceptable levels of risks/hazards. Experts discussed that certain experts tend to support the idea that the underlying mission of public engagement is to convince the public about safety at all costs, whereas, social experts argue public engagement is needed for voice and choice (Ndoh, et al. 2020).

Life science research, such as synthetic biological research, can be defined as research that, based on current knowledge, "can reasonably be expected to provide knowledge, information, products, or technologies that could be directly misapplied to pose a significant threat" (Li, et. al. 2021, pg. 7). These threats include wide range of potential consequences, "to public health and safety, crops and other plants, animals, the environment, materials, or national security" (Li, et. al. 2021, pg. 7). This research assists in appropriately adjusting the existing policies, rules, and regulations regarding the "possession and handling of pathogenic microorganisms and guides related individuals, including researchers, national security officials, and global health experts" (Li, et. al. 2021, pg. 10). The research also emphasizes a culture of "responsibility by reminding all involved parties of the shared duty to uphold the integrity of science" and prevent the misuse of synthetic biology (Li, et. al. 2021, pg. 10).

Policy/Law

The most prominent concern discussed by this group included the economics surrounding the development and distribution of the technology (78x) followed by equity issues emerging from the technology (53x), with public's acceptance of the technology coming in third (51x). In this group, the experts called for a philosophical discussion addressed in a larger societal format in order to garner appropriate public engagement in the case of de-extinction. One of the most challenging aspects of synthetic biology is the "engineering of evolution" (Anderson, Strelkowa, Stan, Douglas, Savulescu, Barahona, & Papachristodoulou, 2012, pg. 587). The possibility that an engineered or "designed biological component might in future generations cease to exist" or may mutate into something unexpected raises important practical, regulatory, and ethical questions (Anderson, et. al., 2012, pg. 587). Evolution and mutation may not fit, at least not neatly, into any of the theoretical frameworks for robustness or modelling, although work in this direction is being conducted both theoretically (Soyer & Goldstein, 2011) and experimentally (Ellis, Wang, & Collins, 2009). Anderson et. al. (2012) states that from a conceptual point of view, evolution, mutation and adaptation can be seen as a "type of discrete uncertainty, in a mathematical sense, that affects the long-term dynamics of a synthetic organism" (Pg. 587). In comparison, intrinsic and extrinsic expressions could be viewed as "short-term continuous effects" (Anderson, et. al., 2012, pg. 587). These statements were made highlighting economic and equity issues in de-extinction:

> *"I think the broader societal issues are sort of what I mentioned before, and it's the relationship of humans with nature and what we think our responsibility is to that. And those are philosophical questions that I think need to be addressed in a larger societal format. I also think we need to—if we're seriously talking about this as an option- really seriously talk about the cost of doing this and what that cost means for other efforts in the conservation movement. So if you start shifting money away from sort of traditional conservation methods towards this, I think we need to have a larger societal discussion about what our priorities are and what we think is worth—where we think we should be spending those precious resources."*

In biomining, this expert group is concerned with governmental and multinational companies having too much influence over the development and implementation of the technology. In other words, the public's interests and engagement may be overrun by these key stakeholders. Gallup, Ming, & Ellis (2021) state that "environmental bioengineering, designing organisms to evolve more rapidly and synthesizing artificial living cells are all ideas that excite scientists but are likely to raise major concerns with a large section of the public" (pg. 57). The greatest future challenge may be for everyone involved in the development, regulation, and distribution of synthetic biological applications "to do their part in engaging with the public, listening to alternative viewpoints, adapting their ideas and making their work and intentions as open and available as possible from the start" (Gallup, et. al., 2021, pg. 57).

The ethical perspective may be to see that "everyone on Earth is a stakeholder, and so all views are valid and should be considered" (Gallup, et. al., 2021, pg. 57). Synthetic biology and its applications may be more readily accepted by the global publics and given the "appropriate regulation that it requires for safe use" and the minimalization of environmental justice issues (Gallup, et. al., 2021, pg. 57). Gallup, et. al. (2021) goes on to emphasize that we have a responsibility to "correctly develop these technologies and use them wisely, fairly and safely to protect and collaborate with nature, rather than exploit and deplete it" (pg. 57). With these sentiments in mind, synthetic biology and its applications will always have even more promise for preserving the planet (Gallup, et. al., 2021). Policy and governance experts stated:

> *"Well, I mean, the worst way to proceed is to just let companies go ahead and do what they want or let the Department of Interior or other bodies just do it. The con with that one is that groups like mine are going to find that they're violating the law, we're going to sue them, and the project is going to be held up in court for a really long time. So, the groups that don't think they need better regulation will end up not having their project become commercialized in a reasonable time. They should look at the genetically engineered salmon at the FDA, which has been there for 18 years now. Nobody's financial plan is going to be—going to sign off on that. So, business as usual looks like the genetically engineered salmon that's been held up for 18 years. The—the next alternative and while—while regulations are difficult, these in—the new industries, you know, it's in their interest to be promoting good regulations that are appropriate to their product to make the—the public feel like they're—they're developing these products safely, and—and to make the government feel like they're developing the projects safely too."*

The policy/ law experts noted that public acceptance might be the biggest issue when it comes to cyberplasm in order for this case to become more commonplace and useful. These statements were made in regard to public acceptance of cyberplasm:

> *"I would say a—a potential broad social issue could be related to technology acceptance on this one. So I wouldn't say it's a given that—that the typical public or person would view this particular technology as they would aspirin, for example. They may not dread it as much as they might dread cancer, but there could be some issues that—I think need to be explored. So—so the—the researchers need to engage the potential communities and the public, and the public's family with respect to this particular technology."*

Lastly, the policy/law group discussed plant microbes on a more global level in order to identify the positive and negative externalities. Food production is seen as a global technology, which is not surprising as the food product import/export industry is played on a global scale. Policy experts state that the assessment of risks should be done by assembling all the different stakeholders, i.e. "government members, the scientific community, industries, security expertise, public health and sanitary personnel, journals and publishers" (Colussi, 2013, pg. 207) . Then, the phase of management "prescribes that the set of actions for addressing the biosecurity needs should be decided through an engagement approach and a multi-stakeholders dialogue" (Colussi, 2013, pg. 212).

Colussi (2013) states that "laboratories and the whole scientific community should be called to draft guidelines and codes of conduct and that the intervention of governments must be meant as complementary with the one of the scientific community" (pg. 211). Colussi (2013) states that it can "consist of delineating the general rules to scientists programs of education and implementation of a culture of responsibility" (pg. 212) should be taught and enforced among the scientific community by research institutions. In this way, "all the actors and all the sources of law are involved in the process, and measures ought to range from ensuring awareness upon single scientists about risks, to laboratory guidelines, from codes of conduct to national laws (both top-down and bottom-up strategies), and international provisions" (Colussi, 2013, pg. 212). In the phases of enforcement and control of the chosen policies, the mixed model based on coordination and integration of tools should be applied. It would entail that judges, government bodies, professional bodies which "represent the scientific community should intervene for the check of the respect of the rules that have been adopted. Such role of oversight should also be vested upon multi-stakeholders' bodies that assemble people from all the different areas of the society, and thus representing the interests of everyone" (Colussi, 2013, pg. 212).

> *"…I think again, care needs to be taken to engage the public to check, you know, to gauge their acceptance of this technology. I don't know if there would be an issue in the United States, but certainly, issues in other parts of the world may impact our ability to export agricultural products to other parts of the world. And if you just continue to do research—and it might be interesting with this particular one to set up some—a system where you're doing oversight or monitoring where you're looking for weak signals that may indicate that this technology is having either positive or negative unintended consequences just so that you have—you may not be collecting a lot of data on things that are maybe low probabilities, very low probabilities."*

Experts disagreed heavily on whether synthetic biology applications needed a top-down or bottom-up governance structure, and experts were not sure if different applications warrant different governance structures. The experts noted that each synthetic biological application may have unique risks that warrant different levels of research into risks. Experts also noted that a risk template may not be able to be designed and therefore economic costs of researching risks would not be able to be estimated (Ndoh et al, 2020). It may be easy to assume that expert opinion on the public's participation would steer towards the historical view but it may be important to be open to all forms of governance on a case-by-case basis.

Ecology/Environmental Science/Toxicology

The most prominent concern discussed by this group included the economics surrounding the development and distribution of the technology (90x) followed by the public's acceptance of the technology (44x), with equity issues coming in third (32x). In the ecology/environmental science/toxicology group, experts displayed that more than one factor may influence each other and, therefore, influence public engagement. In the case of cyberplasm, experts in this group discussed how the economics associated with a synthetic biological application might create a loss of equity (Barendregt, et. al. 2024; Bell, 2004) . These statements were made regarding equity and economics concerning cyberplasm:

> *"I would think that the broader societal issues in this is once you cross the bridge of ethicality and safety, like all new systems like this, I worry a little bit about equity issues and the cost. Maybe there's an analogy for these things: they're not going to be cheap. You know, there was something with hepatitis C that just broke a few days ago. The pills are a thousand bucks a pop, and they're very effective, but it will cost— tens of thousands of dollars for the actual delivery of those systems to people who need them, and it's out of the economic feasibility for many. That's one thing they think about with these new systems as well, but that's no different from any other new drug in the health care option out there.*

"So I think again, the first few cases are going to require a lot of data and a lot of studies to try to get a handle on what are the uncertainties, and once those uncertainties are established, I think risk analysis methods can be used to – hopefully to generalize the results to maybe reduce the amount of testing that would be needed in the future. And to – and then subsequently reduce the cost of developing these new products."

The ecology/environmental science/toxicology group discussed how the relationship between ethics and economics is displayed again in the cases of plant microbes. For biosafety and biosecurity concerns, synthetic biology may cause "intentional or unintentional risks such as food security, and ecological sustainability, despite its enormous economic potential to provide society with more accessible, sustainable, and affordable materials" (Li, et. al. 2021, pg. 11). This statement was made concerning the economics surrounding plant microbes:

"Well, yeah, so the uncertainties are—I mean, I'm going to step away from the uncertainties from the financial end about how effective this method is and whether it's cost-effective. But I mean, with respect to human health and the environment and agricultural health, I think the associated problem—the potential associated problems are again just what are the things—what are the chemical and biological byproducts that are there during the process that are left behind and how they affect the site as well as the nearby environment? I mean, that's the shortest way to summarize it, but that includes a potentially infinite list of possible things that are not always easy to detect, and some of which you wouldn't know were there unless you knew how to look for them in the first place."

The experts in this group noted how, on the one hand, the methodology used in plant microbes is cost-effective overall, but the economic effects on the community in which the methodology takes place could become subversive. Some experts have raised doubts about society's ability to plan for "low-probability, high-impact events, such as the release of a synthetic organism" (Carr 2011, pg. 268). Experts may have doubts about "gaps in the current regulatory framework to oversee privately funded research, especially that of 'do-it-yourselfers' who work outside of agencies, universities, and corporations" (Carr 2011, pg. 268). Even if the laws were sufficient to cover synthetic biology products, the more important issue may be "whether the agencies have the resources and tools they need to both assess the risks of this new technology and to manage the risks" (Carr 2011, pg. 268). This statement was made concerning equity surrounding plant microbes:

> *"So I think that the environmental implications are probably a bit more complex because of the sort of the engineered consortia of microorganisms that are going to be there. I think on the other side of it. I would focus a little bit on the societal implications here; there could be some positives here with respect to, you know, perhaps less energy-intensive ways of extracting—mineral extraction. However, you know, mineral extraction doesn't usually take place in, you know, very affluent areas. So there are some equity issues that probably are going to have to be teased out here, and I think the notion of understanding where these technologies are applied in the context of the communities and or even—you know, rural or, you know, where mining is actually occurring is quite significant and needs to be addressed."*

This expert group noted how both of the points of view would cause similar equity/economic issues. Carr (2011) states that the main challenge, especially as the synthetic biology develops "will be to develop guidelines that are sufficiently cautionary, but without imposing unnecessarily expensive and cumbersome containment requirements that might hinder research" (pg. 268).

STS/Sociology/Philosophy/Ethics

The most prominent concern discussed by this group included the economics surrounding the development and distribution of the technology (66x) followed by the public's acceptance of the technology (59x), with genetically modified foods and equity issues coming in third (50x).

In the STS/Sociology/Philosophy/Ethics group, experts highlighted that in the case of plant microbes, which may be applied in global food production, the economic and political factors may have implications that manifest as equity issues. The experts here highlighted that this industry may always have these issues present. Tackling these issues lie in establishing a dynamic relationship where there is "public engagement on many levels in order to establish relevant public engagement models" (Krick, 2022, pg. 996). This statement was made concerning how economics affect equity issues surrounding genetically modified food in the plant microbes' case study:

> *"And I would think also in terms of the risks and benefits this is also the whole genetically modified foods debate is also one that's just so political it's—and political in terms of all kinds of debates about who, you know, the economics, who benefits, or whom it exploits. I think they're often cast as, you know, providing new food sources and all of this, and then other people counter, 'Well, it's big Monsanto and these other huge multinationals that are actually benefitting.' And so there's a whole economic and political context that underpins the genetic engineering debate, and I think you'd also have to collect data and information around that. Like who are the actors developing*

these synthetic biology variants, how are they connected to industry, and how does that affect people's perspective on these kinds of new approaches?"

Experts in this group noted the equity issues in biomining as they concern the working populations and, by extension, the communities that support these workers. The key stakeholders, labor versus corporate actors, in the case of biomining, may present another dynamic yet symbiotic relationship that must consistently be addressed through public engagement at several levels (Moon, Solomon, Borodina & Vickers, 2023). Empirical evidence supports the importance of diversity, equity, and inclusion. Moon, et. al. (2023) state that diversification can "generate innovative ideas and solutions to many pressing global issues, including climate change, pollution, food inequality, global health, and sustainable production" (Moon, et. al., 2023, pg. 1099). These statements highlight the equity issues surrounding biomining:

"So some of the public or broader societal issues; one is that it might be and because this can have positive environmental consequences or impacts in the sense that it would increase the efficiency and reduce the intensity of the mining industry, there is perhaps a need to clarify what the economics of this technology would look like. That is, it would mainly affect the industrial organization and the reliance on labor within the industry, particularly in countries that are dependent or regions of the world that are dependent on commodities production. Why? If this is seen as one of these technologies that scale and reduce labor considerably, then the opposition would be. So one of the important aspects here is seeing how this would be integrated into different practices so that it doesn't become a source of skill and technology or a technology that has negative economic impacts in local communities."

"So that requires engagement, particularly in regions that are heavily involved in commodities production mining, and that can be addressed through the sort of standard, if we want to call them, within merging which is involving stakeholders in the process of technical change, trying to also involve communities that are related directly to a close range of stakeholders in order to understand how these policies can be negotiated in the long run and to create also novel points of intervention that would guarantee that this does not have these negative economic impacts locally."

Lastly, experts in this group explored the relationship between public acceptance and uncertainty in outcomes in the case of de-extinction, which manifests as benefits/risks on a societal level. The STS/Sociology/Philosophy/Ethics group essentially asks, 'Why do it'? De-extinction presents circumstances, genetically and ecologically, that, globally, all the public would have to deal with. This group ponders what the perpetual benefits and/or risks will be, should be, and could be (Ndoh, et al. 2020). These statements were made in regard to de-extinction and the public's acceptance of the technology:

"Well, we're talking about the uncertainties about pathogens, but I'd say a major reaction would again be the public reaction to this particular type of research. If—if, for example, experts are trying, you know, make some progress in de-extinction like, say, ten different species and—and for whatever reason, they all, you know, die in infancy or they come out malformed, or—it could just turn into a horrible experiment and tarnish all of science. And—and, you know, the benefits of de-extinction [of] a species would certainly not be worth tarnishing the broader scientific enterprise."

A essential driver for the integration of social and biological sciences in the field of synthetic biology has been a "collective desire to avoid the mistakes of the past, where science and industry largely neglected to consider the social dimensions of proposed genetic modification of agricultural commodities" (Calvert, 2013, pg. 184; Fisher et al., 2013). These omissions have led to diminishing trust in scientists and their organizations due to opposition and fear in certain sections of society. The spreading of negative messaging toward biotechnology "culminated in a global cultural phenomenon where the mere mention of genetically modified can render a technology or product inert and its developers branded social and institutional pariahs" (Calvert, 2013, pg. 182).

To overcome some of these past mistakes, science institutions have promoted a holistic approach to solving global challenges, such as, "by requiring funding applicants to identify the ethical and social considerations of the work they intend to conduct" (Carter & Mankad 2021, pg. 2), therefore addressing environmental justice concerns by default. Carter & Mankad (2021) go on to state that "there is rarely a sufficiently strong accountability mechanism that requires research teams to follow-through on addressing the social impacts identified" (pg. 2).

One expert in the study highlights this sentiment in the statement below:

"But I think it speaks to a clear kind of moral debates that are being had right now, and questions about public good that maybe can't be regarding risks and benefits. But I think these kinds of—I mean, if you want to frame them as risks and benefits in that—I guess talk about the social and political risks involved, which requires research as well. So I think understanding the nature of those risks is in some ways just as important as understanding the nature of the potential environmental and safety risks you're dealing with."

Experts pondered how economics may affect long-term research into risks associated with synthetic biological applications. Experts postulated if the concept of the control of synthetic biology technologies is being used to increase and influence the decision-making power of the public or if it is being used to garner a path towards acceptance of said technology that would result in experts having more autonomy. Experts agreed, at varying degrees, that value systems of different publics should be taken into influential consideration, especially if those value systems differ from that of the scientific community and if, they are directly affected. They also noted that the differences could lead to impediment of the development of the synthetic biology technology and its applications. One specific example of an environmental justice issue was identified in that "traditional and accepted knowledge within the social and behavioral sciences applies largely Western framings of science, where scholarship has typically neglected traditional knowledge systems developed by others, particularly indigenous and local communities" (Carter & Mankad 2021, pg. 3; Mazzocchi, 2006). In the emerging technology context, this framing limits the "exploration and identification of other complex sociocultural factors" (Carter & Mankad 2021, pg. 2; Delborne, Kokotovich & Lunshof, 2020)

For some research groups, intensifying multi-disciplinary integration can be paramount to obtaining "social licence" for a specific synthetic biological application and its public adoption (Carter & Mankad 2021, pg. 2). Researchers stated that "social license aspiration can invoke a transactional paradigm of engagement with the anticipated end result being a rubber stamp of approval" (Carter & Mankad 2021, pg. 2). Carter & Mankad (2021) states that without sufficient oversight from independent engagement practitioners, "a social license agenda can shift an intended engagement goal to a campaign of (re)educating the public on the benefits and impacts of a proposed novel application" (pg. 2). Carter & Mankad (2021) go on to state that genuine integration requires mutual respect for other disciplinary and interdisciplinary approaches and trust that other disciplines have the technical know-how to understand the "various moving parts from their own distinctive lens" (pg. 5).

Case by Case

Figure 3 shows the percentage of comments made in each thematic pattern per case study. Question 2 asked if these thematic patterns would vary depending on the synthetic biological application. One of the most prominent results that answers question 2 is that the theme of genetically modified foods is discussed significantly in the case of the engineered plant microbes, mentioned by the experts 91 times. Being that they are both tied to agriculture, public outreach efforts, although not nearly as often as genetically modified foods, were discussed by experts, at least as much as the engineered plant microbial case study. During the discussion of cyberplasm, experts discussed public acceptance, apparency (54%), public education, transparency, and the social contract of experts more than any other case study. Cummings and Kuzma (2017) made this same discovery, noting how the "uncertainty" of the application may influence the public's response to it. During the discussion of de-extinction, economic implications were mentioned 42 times, as was with biomining. Public acceptance was also very highly discussed 34 times, with the case of de-extinction. De-extinction is a highly novel case, which is perhaps why public acceptance is mentioned more (Cummings and Kuzma 2017; Ndoh, et. al. 2020). In the case study of biomining, the discussion of issues that may arise in other countries, namely under industrialized countries, control of the technology, issues of equity, information sharing, and issues surrounding knowledge are discussed more than any other case study.

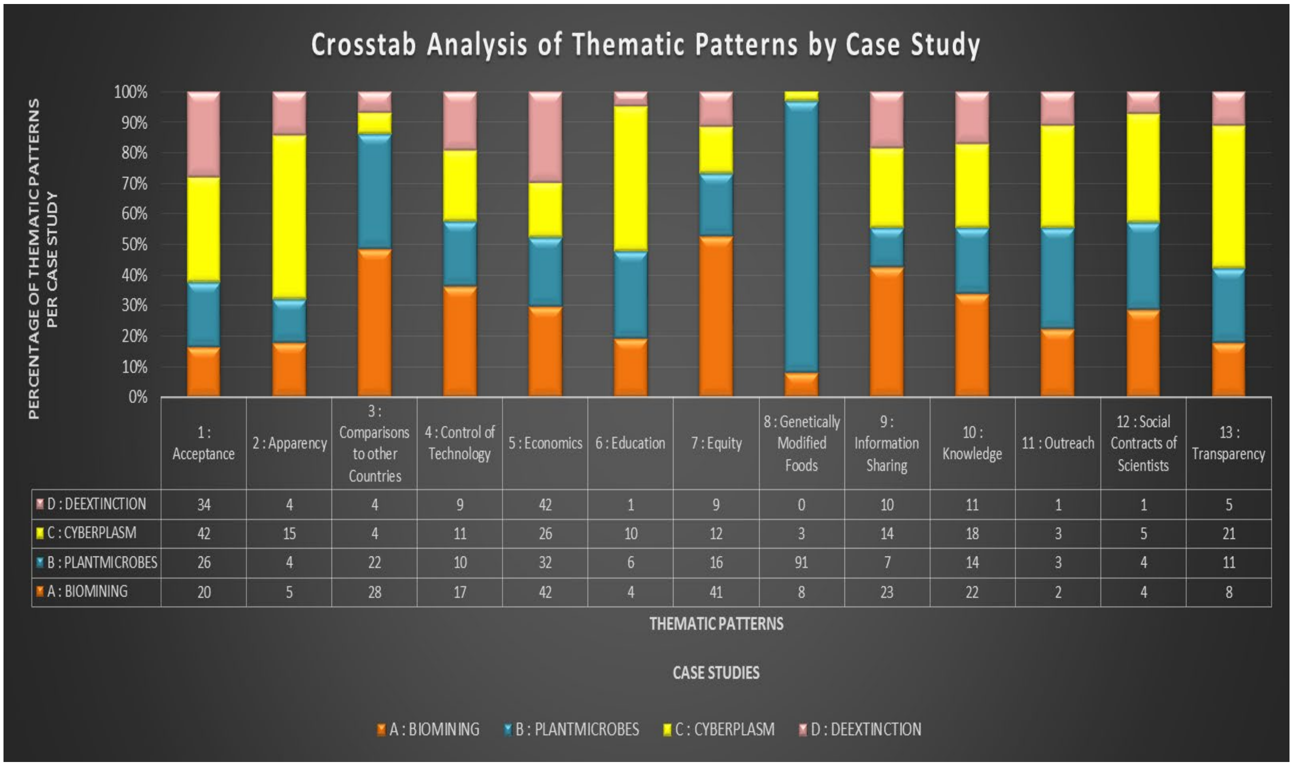

Figure 3: Crosstab Analysis of Thematic Patterns by Case Study.

Biomining

Policy/Law experts discussed the regulatory aspect and the health benefits of biomining. Biomining generally produces fewer greenhouse gas emissions and less waste material, thereby contributing to less land degradation and pollution (Mohan & Joseph, 2020). Efficiency assessments indicate that biomining processes can achieve similar or enhanced recovery rates when compared to conventional techniques (Mohan & Joseph, 2020). There have been innovations in biomining, automation and practices. These innovations are “reshaping mining operations, improving environmental impact and operational efficiency, and emphasizing resource stewardship” (Mohan & Joseph, 2020, pg. 169). Mohan & Joseph state that supportive policies and investments as well as collaborative efforts across sectors, are crucial in redefining the mining industry's role as a responsible and essential resource provider in the global economy

(Mohan & Joseph, 2020). These statements were made by the Policy/Law group concerning the potential impact on the workforce and the environment:

"*Some of the uncertainties would be related to how the microorganisms with the environment, whether there might be containment issues, which have to do with both the nature of the microorganism, the context in which it's going to be used, and the regulatory in the countries where it is being utilized. So that's one issue, the containment, which is again in biotechnology and biotechnological applications. The other one has to do with economic uncertainties in the sense that we don't know how this will reorganize the industry. It can have a profound effect on a series of productive processes that are very dependent on labor. So there might be unintended problems associated with that, and, again, those are very uncertain because we don't fully understand, from what I can tell, the economics of this technology.*"

"I would say that the health impacts are minimal besides the people doing the actual application of the microorganisms. So, if there were health impacts, immediate health impacts would be for actual workers on the actual mining site and potentially those developing—the microorganisms. But I don't see health impacts as the—a real sort of threat in terms of bio-mining. The environmental issues, I guess, are far-ranging, depending on the specific microorganisms that you're developing, where the actual mine towns are, the volume that you would have to use for each particular mine site, and then also the potential reclamation facilities or methods that they would be using at the actual mine site."

Science & Technology/Sociology/Philosophy/Ethics experts called for a broader assessment of issues beyond technical risk, like socioeconomic issues. Some researchers believed that empowering local communities is essential for sustainable mining solutions (Mohan & Joseph, 2020). This can be done by "creating employment opportunities, infrastructure development, and educational programs benefits both the industry and local populations" (Mohan & Joseph, 2020, pg. 172). For example, some African mining projects often include initiatives to build schools and healthcare facilities in nearby communities (Mohan & Joseph, 2020).

The economic viability of biomining largely hinges on factors such as operational costs, metal prices, and regulatory frameworks (Mohan & Joseph, 2020). In comparison to traditional extraction, which often involves high energy consumption and substantial environmental rehabilitation costs, biomining can reduce energy use by up to 30% and significantly lower the need for water (Rico, Font, Bherer, & Smith, 2021). Additionally, the investment in biomining techniques can be offset by reduced extraction costs and higher recovery rates of certain metals like copper, gold, and rare earth elements. As industries seek to meet stricter environmental regulations and pivot towards greener technologies, the long-term economic forecast for biomining looks promising (Rico, Font, Bherer, & Smith, 2021). These statements were made by the Science & Technology/Sociology/Philosophy/Ethics expert group concerning the potential impact on the risk and uncertainty:

> *"Risk analysis is the discipline that encompasses re-components. The first component is called wreck assessment, which is an ethical process that has to be done by an expert. The second component is called wreck management, which needs political production because it takes into account many issues other than technical issues, such as social and economic considerations. The sub-component of wreck analysis is wreck communication. Of course, you do the wreck communication and how and to which audience. When you*

talk about risk analysis, we understand that you are talking about the discipline of wreck analysis; you are not talking about risk wreck assessment…"\

In the case of biomining, the biochemical/microbiology/chemistry/engineering expert group is leaving decision-making powers to technical elites and managers, which is a deficit model framework. Governments play a pivotal role in enforcing environmental standards and promoting sustainable mining practices. Stricter policies can mandate water recycling, pollution control, and land rehabilitation (Mohan & Joseph, 2020). Incentives like tax breaks or subsidies for adopting green technologies encourage industry compliance. For instance, Canada's federal regulations require mining companies to invest in ecosystem restoration. Partnerships between governments, mining companies, and environmental organizations foster innovation and accountability (Mohan & Joseph, 2020). Joint initiatives such as the Responsible Mining Index track and promote sustainable mining practices worldwide and collaborative research projects can accelerate the development of eco-friendly mining technologies (Mohan & Joseph, 2020). These statements were made by the Biochemical/Microbiology/Chemistry/Engineering expert group concerning the potential impact country to country, developing nation versus developed nation:

"You need to be very aware of this because what applies to the rest of the world does not apply to the US because they are very clever, and I applaud them; that's new. You didn't find the Santa Hannah protocol because it is mainly managed by the ministries of the environment. In this case, it is a mining issue or a trade issue, but it will be managed by the Ministry of Environment in most countries. When it comes to agricultural products, it's an agricultural issue, but it's also managed by the Ministry for the Environment. Just

to go specifically to answer the point of your question, I think this has to be an effort and a multidisciplinary effort as well.

Several institutions in this regard would be Chile, which might have a ministry of mining; Libya, which has a ministry of mining because mining is important; and Hungary, which doesn't have a ministry of mining because mining is particularly unimportant. The Ministry of Health might be involved, or the contamination might not necessarily affect human health. Each country will have to decide what to do, and the more people and the more organizations you involve to become participatory and politically correct, the more complex it is for you to get.

To summarize I will say the two key groups that you need to involve are professional risk analysts and risk assessors with managers and risk communicators and you need to involve obviously the professionals that are developing this technology that understand what they are doing, the molecular biologists, the micro biologists, and the mining engineers they have to be a multi-disciplinary team."

The ecology/environmental science/toxicology expert group called for a more participatory assessment of public engagement with concern for governance issues. These statements were made by the Ecology/Environmental Science/Toxicology expert group concerning governance issues:

"…I think a very top-down, I mean, I tend to think that because this is so complex, that a much more participatory governance structure needs to be in place, and I would be in favor of that. Also, the co-development of that governance structure is not only the stakeholders who are going to be impacted but also those who are linked to the technologies and understand the technologies. So I would be—yeah, I think a governance

structure that acknowledges a diversity of stakeholders as opposed to a very top-down, you know, Administrative Procedures Act kind of approach that really is not adaptive is not going to be beneficial. I think the cons of that top-down approach really are that it disconnects stakeholders from the implementation of a new technology that does."

The analysis of expert opinion within the case of biomining illuminated several issues. These issues included the equitable distribution of benefits, differences in the developing countries versus the developed country, future ecological and environmental effects (and therefore the costs of those effects over time), and the displacement of those working in the field of mining but who are not skilled to work with the new technology, therefore creating disparaged communities (Fischer, Wentholt, Rowe & Frewer, 2014). Historical oppression and dangerous working conditions may affect areas of public acceptance and control of technology depending on the relationship between key stakeholders (Rico, Font, Bherer, & Smith, 2021). .

De-extinction

In the case of de-extinction, policy and governance experts are calling for engagement early on, which is designed to be expansive. Early public engagement, especially in the early development of technology, may influence educational, economic, equity, and acceptance issues early on (Krick, 2022). This statement was made by experts in the Policy/Governance/Law group concerning public acceptance:

"…because of the Frankenstein-like perception that—that the general public might take on, engagement with—with the public well in advance of the time that this could even get out of the laboratory would have to take place extensively. There would have to be a dialogue, and it would be problematic, but this is not the kind of thing that you could sort of hide in a basement and then all of a sudden spring on somebody and say, "Hey, here's

the greatest thing since sliced bread." It's—this has got to be a—there's got to be a lot of outreach to even get this started. From that, maybe then it would involve the oversight mechanisms that are appropriate for it…"

De-extinction poses new challenges for how species are categorized and understood frp, a regulatory context. Nature conservation may be a potential area of regulatory control and "that the scientific processes used in de-extinction projects will impact the taxonomy and hence the legal status of a de-extinct species within a given regime" (Allen, Doyle, McCorristine & McMahon 2020, pg. 321). Allen, et. al. (2020) stated that it "runs the risk of creating an oscillation between endangered, extinct and re-created species, which could have ramifications for nature conservation given its traditional focus on conserving species currently in existence" (pg. 321). De-extinction attempts, if successful, will create a challenge to the "notion and significance of traditional legal cornerstones such as 'extinction', 'endangerment', 'naturalness' and 'wildness' as animals and de-extinctees oscillate between such concepts" (pg. 321). These experts go on further to state that these concepts are "key to existing conservation frameworks" and to how legal protections become applicable within those frameworks (Allen, et. al. 2020, pg 321).

Allen, et. al. poses some interesting questions. These experts wonder "if it is possible to recreate extinct species, what then is the significance (if any) of attaching protection according to extinction risk? To what extent (if any) should legal protections be granted to de-extinctees? Should governments be under a duty to engage in de-extinction attempts for extinct animals? How should de-extinction be balanced with conservation projects in terms of funding and resources? How should legal protections be developed to facilitate regulatory priorities in terms of de-extinction and conservation attempts?" (pg. 319). Legal questions like these highlight if and how “animals should be prioritized for de-extinction attempts” (Allen, et. al. 2020, pg. 319). De-extinction attempts, if intent upon release into the wild, could “threaten ecosystems for existing species and therefore raise difficult questions about how de-extinction and ecosystem survival should be negotiated in such contexts” (Allen, et. al. 2020, 321).

Ecology/Environmental Science/Toxicology experts focus on ecological impacts, as one would expect for this group, but it is a real concern for the public and other types of experts. Some experts question whether a de-extinctee would resemble its ancestors, or even represent the return of a ‘species’ at all, “given its environmental and epidemiological differences with the extinct animal, its synthetic birthing and the lack of any existing habitat” (Allen, et. al. 2020, pg,. 312). De-extinction will likely pose questions for how we conceive ‘endangerment’. This may create a challenge to “existing conceptions of how biodiversity is defined or should be ‘conserved’” (Allen, et. al. 2020, pg. 312). The scientific processes used to facilitate de-extinction may bring its own can of worms. For instance, “it is only de-extinctees created via cloning that are genetically similar to the existing animal”? (Allen, et. al. 2020, pg. 313).

The motives for reintroducing a species include but are not limited to restoring species biodiversity and variability; rejuvenating declining ecosystems via the (re)introduction of environmental engineers; replenishing a depleted food source or creating a new one; or even regenerating commercial revenue via the resurrection of animals” (Allen, et. al. 2020, pg. 13). But there may be other motives that are not environment friendly or pose great risk to the environment or to human health. For example, the motivation of some de-extinction projects could be profit, by “seeking to reap the financial benefits of creating an extinct animal well-known within popular culture (e.g. the woolly mammoth) and making the animal a spectacle”. Political motivations may also be a factor (Allen, et. al. 2020, pg. 314). This statement was made by experts in the Ecology/Environmental Science/Toxicology group concerning resources being used for this technology versus addressing other needs:

> *"…if you do have a population of viable organisms like this, it does need close monitoring because it's never been done, and we really don't know what's going to happen to the environment. We really don't know any potential negative effects that could take place. The cons are just, again, the resources being invested in something that is relatively minor—if you think of the problem of biodiversity and conservation as an ocean, this is a very small drop in the ocean in terms of solving that problem. It's—it's a spectacularly interesting thing to do and study, but I would—I would—the con is just the amount of governmental agencies and—and money that would be required to go into monitoring something like this."*

Biochemical experts' statements, again, exemplify facets of the deficit model but also call for early-on public engagement through knowledge and education (Krick, 2022). The statement was made by the Biochemical/Microbiology/Chemistry/Engineering expert group concerning the morality of this technology:

> *"I guess I will just make a point here that it's relevant to everything, but it's very relevant to the fact that we need to educate our students from a very early age on two things. One that genetic manipulation is not a big deal, genetic engineering is possible, it's not evil, it's not against God that takes synthetic biology and creating artificial genomes is not possible. If you teach that to kids from an early age, then it's freely going out the window like a four-year-old or a two-year-old being shown an iPad, which is not a big deal. If young kids get exposed to this science from the very beginning, then they are not going to do a trade of it, so that's the first thing."*

STS experts, in this case, discussed the possible unintended impacts of this technology, which concludes the pattern. If the de-extinctee is genetically and taxonomically identical to an extinct animal, "such as a cloned animal which derives its DNA wholly from an extinct counterpart, its legal status would arguably be the same as the legal status accorded to the extinct animal" (Allen, et. al. 2020, pg. 316). But how will the legal status of a newly extinct species be determined? Neither the United States nor European Union systems have detailed provisions on the listing of species "supplemented by any provisions on the potential de-extinction of a species" (Allen, et. al. 2020, pg. 317). One the other hand, extinction of key species can cause ecologic imbalances and de-extinction can become a powerful conservation tool. It may be used to rescue "ecosystems from collapse and preserving delicate balances. Conservationists frame de-extinction as 'deep ecological enrichment' or restoring ecosystem functions lost through extinction" (Allen, et. al. 2020, pg. 318). The primary catalyst to releasing resurrected animals into suitable habitats is because of the benefits of increased biodiversity and ecosystem resilience (Allen, et. al. 2020). These statements were made by the STS/Sociology/Philosophy/ Ethics expert group concerning the release of organisms in the ecosystem:

> *"…are these de-extinction for captivity, or are we reintroducing species into ecosystems? There are recent studies showing that the reintroduction of wolves into Yellowstone National Park has actually had a really interesting, and I think a lot of people agree, net positive impact on the area within the park. The ranchers nearby aren't very happy, but they—you know, that is a de-extinction that happened only within the last 60 years, so the—a lot of the plants and animals in the area hadn't adapted wildly, but if we bring something back from 1,000 years ago or even farther, that can have a much more significant shift."*

"So I don't know if it would be possible to actually have oversight to ensure that everything remains in labs and in zoos, but I think that will probably fail to some extent. But I think if there is a focus to keep things within zoos and labs then actually the broader social and governance context isn't wildly affected."

The analysis of expert opinion within the case of de-extinction highlighted control of technology and acceptance issues. Experts posed the inquiry into control and creation of life, "playing God," and garners questions such as whether there should be patents or trademarks on these creations that result from this technology (Barendregt, Bendor & van Eekelen, 2024). Experts discussed the influence of "The Mad Scientist" and "Frankenstein" on science fiction, and this case showed the good and the bad aspects of the scientific imagination. The experts stated that science fiction is an information sharing technique to may make real scientific concepts understandable to public. Experts thought that science fiction may be used to assess how the public will react to future applications of synthetic biological applications (Barendregt, Bendor & van Eekelen, 2024). Experts were especially interested in the effects and risks when these creations are released into the environment and what it says about public acceptance if economic resources were used to bring back an animal that will only be used in the lab, just to say that it can be done instead of something that could have benefited society at large. Expert opinions diverged on the purpose of the outreach strategies and if these strategies should be expansive or locally sourced. Experts also raised questions of how to create outreach efforts that facilitate a meaningful conversation around the technology and how to ensure the authentic participation instead of consensus with synthetic biology developers (Fischer, et. al., 2014) .

Plant Microbes

In the case of plant microbes, the Biochemical/Microbiology/Chemistry/Engineering group, as a pattern now, has deferred to the technical elites. This statement was made by the Biochemical/ Microbiology/Chemistry/Engineering expert group concerning who should evaluate uncertainty:

> *"The uncertainties are complex to evaluate, but professional risk analysts know how to tackle these questions, but they are none professionals. I will make a point here in the GMO… [Genetically Modified Organism] ...oversight in the US professionals are there, and you have GMO's in the US, in Europe and other countries, especially in poor countries all kinds of people are invited into the debate and anybody who spends a little time reading on the internet what has been written about GMO thinks he is an expert and thinks they have the right to acquire because they eat food and they have some identification with agriculture."*

Carter & Mankad (2021) stated that a "fundamental hurdle to true science integration in synthetic biology is the valuing of unique contributions of other disciplines in helping to write the complex story that is innovation" (pg. 5). They urged research leaders and administrators to "resist micromanaging alternative science output when methodological approaches do not fit the "experimental science" mold or when non-traditional knowledge processes might be more suitable" (Carter & Mankad 2021, pg. 5). Throught a collaborative context, experts must view their "comparable training for their craft and differing philosophical positions" as a strength rather than a barrier. An multidisciplinary environment where experts are "trusted and governed accordingly fosters intellectual freedom which has the potential to yield impactful outputs on a global scale" (Carter & Mankad 2021, pg. 5). The researchers stated that the value of both biosciences and social sciences is obvious than when a technology is thought to be a game change in the laboratory, only to realize that there is no social "pull" for a technological solution in its application. Recognizing the mutual value of a multi-disciplinary approach to an innovative solution, or revolutionizing an industry for a local community, "will help to foster trust and redress any perceived imbalances across disciplines" and for the public (Carter & Mankad 2021, pg. 5).

In contrast, the STS experts discussed the unintended consequences and how they cannot always be foreseen early on. Therefore, those impacts to the public need to be considered when creating governance systems for synthetic biology which in turn, minimizes environmental justice issues from the beginning. This goes back to maintaining a dynamic relationship among and between disciplines as well with the public, as these types of relationships need to be constantly cultured to stay relevant (O'Keefe & Hogg, 1999). These statements were made by the Science & Technology/Sociology/ Philosophy/ Ethics expert group concerning containment issues:

> *"…the problem is you could produce a bio microorganism, a synthetic microorganism that could end up destroying the crops with one set of mutations, and that it's hard to imagine that happening, but you'd have to be able to - that's why you have to some containment strategy for the first use, and it could be that the changes in the crop don't show up for two generations, two or three generations, so you'd have to have a long period of testing before you'd release it."*
>
> *"Well, each organism has to be tested carefully, there have to be containment facilities for the organisms, and what's interesting is the problem with any plant technology is that there's been a tragic history of use of GMO, genetic modification for food, GMO food,*

and the reason this happened was that the plants were engineered not to be able to be used…"

Experts expresses environmental concerns about releasing synthetic biological microorganisms that must be addressed. They called for the development of robust biosafety, biosecurity, and biocontainment strategies for the use of genetically modified microbes in the environment. Several US agencies have initiated programs for biosafety, biosecurity, and biocontainment strategies (Obama White House, 2015; Safe Genes program, Darpa, 2017) to "increase understanding of how synthetic DNAs and genetically modified microorganisms behave under various environmental conditions and across diverse organisms for multiple generations" (Ke, Wang & Yoshikuni 2021, pg. 244). Biosafety and biosecurity concerns also include "horizontal gene transfer of synthetic DNA and the emergence of microbes harmful to the environment that are difficult to eliminate (pg. 244)" and developing tracking systems to monitor releases into the enviornment (Ke, et. al. 2021).

Policy/governance/law experts present a more balanced view of benefits and costs across more populations, an opening again to early public engagement (Fischer et. al., 2014). There may be a common fear that involving public stakeholders 'too early' may derail projects or place an artificial ceiling on key exploratory science before projects even get off the ground (Fischer et. al., 2014). Is this fear well-founded and should investment in synthetic biology research be pursued if the public were to reveal "ambivalence or disapproval, given that much of the exploratory research in synthetic biology is publicly funded" (Carter & Mankad 202, pg. 3) . Experts agree that public dissension towards synthetic biology and its applications may be because broader socioeconomic conditions are not adequately considered or planned for. Even if the "highly successful proof of concept technologies within a research institute or academic setting can be positioned as having enormous triple-bottom line impact value" (Carter & Mankad 2021, pg. 4). This statement was made by experts in the Policy/Governance/Law group concerning potential impacts on health and the environment:

> *"… There could be many positives from the use of engineered microorganisms in agricultural applications. It could decrease harmful environmental practices; it could reduce the use of noxious chemicals. It could improve the efficacy of food fiber or fuel production. So there are a lot of benefits that I can see from synthetic biology being used in this space."*
>
> *"The possible negatives are the ones that everybody always mentions, which are these organisms – how long are they going to survive once they get in the environment? What are they going to do once they get in the environment? Are they going to start competing for resources, space, and mates? Are they going to start using resources that other organisms in the environment need? Are they going to change ecological processes? Are they going to produce toxins, so on and so forth?"*
>
> *"So there are a number of different implications for the environment, both positive and negative, from these – from engineered microorganism applications in our culture."*

Microbes associated with plants have enormous potential for economical and sustainable agriculture (Ke, et. al., 2021). There are two approaches to plant microbiome engineering. The first approach is the bottom-up approach that involves isolating, engineering, and reintroducing specific microbes. The second approach is the top-down approach that involves synthetic ecology, using horizontal gene transfer to a broad range of hosts in situ and then phenotyping the microbiome (Ke, et. al., 2021). Recent advances in "genome engineering tools, metaomic tools, computational tools, and genome-wide functional genomics" can improve the ability to engineer microbes for "biocontrol, biofertilization, and biostimulation, as well as enhanced crop productivity and yield" (Ke, et. al., 2021, pg. 257). It is also important to note that various devices have been developed that can facilitate the evaluation of genetically modified microbes before they are introduced to field tests (Ke, et. al., 2021).

The Ecology/Environmental Science/Toxicology group's quote broadens the discussion globally. Again, a pattern emerges where implications from food production and plant microbes coincide with global markets. As globalization increases, international cooperation regarding biosafety governance is necessary. To respond to the possible risks and threats from synthetic biology, countries are highly recommended to strengthen various measures such as "strengthening the top-level design of biosafety, and stepping up the formulation and improvement of national laws and policies" (Li, et. al. 2021, pg. 11). In addition, countries are advised to focus on the overall biosafety and biosecurity education to achieve a weighty contribution to the governance of technology globally (Li, et. al. 2021). This statement was made by experts in the Ecology/Environmental Science/Toxicology group concerning globalization and implementation issues:

> *"Yeah, one—one—just one other thing, and again, it's another theme that I've put forth early on, is sort of understanding the notion of intentional agriculture and where it plays out, whether it's in the developed world or the developing world and how these technologies are applied has some issues—it's issues of—that relate it to things like globalization and equity. And so that—that's another piece of this puzzle, where oversight is—needs to come into play. I mean, you know, globalization of agriculture is having big impacts around the world. I mean, you can look at Brazil, you can look at Africa, you can look at other places where—where, you know, the implementation of, you*

know, technology-driven agriculture has broad implications environmentally, to the extent that this new technology will enhance that, or change it, or, you know."

The analysis of expert opinion within the case of plant microbes highlighted connections to climate change and food production, which are some of the largest and most pressing global issues to date. Experts agreed that this case would warrant questions and solutions towards the needs of the poor, visual versus non-visual influences on the perception of the public, ecological and environmental contamination issues, and long-term risks (O'Keefe & Hogg, 1999).

Cyberplasm

In the case of cyberplasm, Policy/Governance/Law group and the STS/Sociology/ Philosophy/Ethics group discuss issues around how controversial the health implications could be (Krick, 2022). Researchers from the Engineering and Physical Sciences Research Council (EPSRC) define cyberplasm as a tiny prototype robot that functions like a living creature is being developed which one day could be safely used to discover and uncover diseases within the human body. These researchers state the robot would respond to light and chemicals in the same way as biological systems, allowing it to navigate its way through the body collect data from its surroundings, including information on the presence of disease. The sensors being developed for cyberplasm could also find applications in areas such as advanced prosthetics by enabling living muscle tissue to be controlled by light waves or electronic signals (Engineering and Physical Sciences Research Council 2012). This information will be then used by the brain to send electronic messages to artificial muscles, telling them to contract or relax, resulting in an undulating motion which propels the cyberplasm and allows it to navigate through the human body (Engineering and Physical Sciences Research Council 2012). Data on the chemical make-up of the robot's surroundings can be collected and stored for later recovery, information later used for diagnosis. Theorectically, cyberplasm it will combine advanced microelectronics with the latest research in biomimicry (Engineering and Physical Sciences Research Council 2012). The aim is for cyberplasm to have an electronic nervous system, 'eye' and 'nose' sensors derived from mammalian cells, as well as artificial muscles that use glucose as an energy source to propel it (Engineering and Physical Sciences Research Council 2012). This statement was made regarding medical applications by experts in the Policy/ Governance/Law group:

> *"…And I have to admit this one really struck me as, you know, pretty theoretical at this point, whereas the others didn't. And so I want to be really careful about what I say in this one because, again, it's way out of my field. I mean, I, you know, I think what's interesting to me in this is it seems, at least as the case is presented, very health-related. You know, we'll have the case of this free-swimming electronic-brained organism that might potentially do things like drug delivery and health care. You know, it seems to me that there could be some very positive implications, particularly if it's constructed in a way that it has very little likelihood of existing outside of the context of its application."*

This group also pondered what would happen if the development of the application, controlled or uncontrolled, reached beyond the initially stated and intended purpose (Barendregt, et. al., 2024). This statement, also made by experts in the Policy/Governance/Law group, concerning control of technology and transparency:

> *"…So that intent needs to be clear, and we need to be accountable and also responsible about these choices that we are making. So, I think the broader societal issues here are because we are talking, unlike the previous case, which was an industry-sponsored activity. This one is public tax dollars being used for a public good purpose, so this is a different situation than the bio-mining one. Here, we need to gauge the public value and*

map it as we are making these investment decisions and making sure that we also set up the right tools and measures so we can evaluate and make course corrections where necessary. So, the broader societal question here is: How do we organize the scientific enterprise in a way that sort of helps us achieve desirable social outcomes? So it's a little bit different than the bio-mining case and much broader in scope and design…"

As was pointed out with the case of plant microbes, creating effective biosecurity procedures and policies to protect humans, agriculture, technology, and the environment from nefarious usages (or accidental or negligent damage from misuse) will require understanding the current state of synthetic biology, in the case of cyberplasm (Trump, Florin, Perkins & Linkov 2021). This includes knowing the platforms and technologies available for manipulation or construction (e.g., viruses, microbes, multi-cellular organisms, or cell-free systems) and planning for the future as the field overcomes identified bottlenecks or roadblocks (Trump, et. al., 2021). Biosecurity will require developing screening mechanisms for synthetic pathogens and biological attacks, as well as methods to assess how a synthetic pathogen could be dispersed during an attack, identify what the potential targets of the attack. (Trump, et. al., 2021).

This statement was made in regard to potential impacts on health and the environment by experts in the STS/Sociology/Philosophy/Ethics group:

"So I see cyberplasm as being targeted mainly at trying to improve human health by using basically not quite an artificial organism but sort of these hybrid – bio hybrid organisms. And could be for monitoring, or it could actually be for treatment, so potential health impacts, I think – I would think that the environmental impacts are probably less significant than the potential health impacts. So the application of one of these organisms for either monitoring or treatment I think would be particularly the first

applications would be highly controversial and potentially risky since they'd be sort of unprecedented in our history of treating diseases."

In contrast, the Biochemical/Microbiology/Engineering group highlights all the possibilities possible through continued research of this technology and the benefits of society, yet another technically optimistic role. This statement was made in regards to uncertainties surrounding cyberplasm by the experts in the Biochemical/Microbiology/Engineering group:

> *"So I think the uncertainties here are very high, because again I think this is sort of an unprecedented avenue of research. So I would think this is something that needs a very thorough research phase before it's ever applied to real problems. So I think there's a high degree of uncertainty that would require a large amount of research. So I think the risk analysis again, let's assume that they're not reproducing, then I think the risk analysis methods are those similar to drug treatments. And I think they would be very applicable. If they are designed to be reproducing, I think then it becomes a combination of those types of things and risks associated with modeling of infectious diseases. And I think that could make these much more problematic."*

Equity—specifically, access to this technology, due to its medical applications will look different from country to country (O'Keefe & Hogg, 1999). For instance, although the European Union legislation on synthetic biology has been continuously updated over the last two decades, the European Union's legal framework has been criticized as not being sufficiently comprehensive in scope, and proposals have been made to modify it to suit the rapid development of biotechnology and the new era of synthetic biology (Li, et. al. 2021, Johns Hopkins Center for Health Security, 2019). Considering the bio-risk concerns, China has promulgated laws and regulations on biosafety governance of synthetic biology for laboratory practice to secure biosafety and biosecurity. The Standing Committee of the National People's Congress, the representative of China's supreme legislature, distributed the Biosafety Law of the People's Republic of China in 2020 (Li, et. al. 2021). The Biosafety Law generally stipulates the security management of biotechnology research, development, and application activities, and of pathogenic microbe laboratories. The law also calls for the development of standardized laboratory biosecurity standards. Any administrative regulations, local regulations and department rules cannot violate this Biosafety Law (Li, et. al. 2021). This statement was made in regards to how different countries may respond to cyberplasm technological development by the Ecology/Environmental Science/Toxicology expert group:

> *"Again I would see that this would have to be regulated at a national and international level, because if you're developing treatment regimens for diseases or monitoring it would – I would assume that they would want to use these in multiple countries. So I think there would have to be some regulation and some examination at the government level, but I think there would also have to be international cooperation to see that if something is developed it can be used as widely as warranted."*

The analysis of expert opinion within the case of cyberplasm highlighted how education, knowledge, and data gaps may manifest themselves due to fear of the unknown and how these devices may look (Krick, 2022). Information sharing to the public as well as apparency and transparency concerns may also present uncertainty. Experts agreed that a stronger public reaction toward why certain synthetic biological applications are being developed or explored on a case-by-case basis creates more scrutiny for many experts and regulators disrupting the current status quo (O'Keefe & Hogg, 1999). Certain assumptions and biases may influence the level of apparency to be given to and shared with the public at large if, experts assume the 'low understanding of the public'. Experts disagreed on what level of apparency should be given to the public and for what reasons (Rowe & Frewer 2000). Even more experts in this study discussed how the public's fear would affect how transparent it would be and how this fear may influence what experts would or should share, behave, or say (Ndoh, et al. 2020).

Conclusion

This exploratory study's findings have implications for experts and policy makers who are interested in public engagement practices. This is because the findings are likely to be of use to expert groups and decision-makers fostering the interconnections between stakeholder groups and public engagement with science and technology development (which can help to address environmental justice concerns by including diverse publics), and public policy (Krick, 2022). This study in public participation is important to give voice to diverse publics so that marginalization and disproportionate negative externalities created as a by-product of emerging technologies, are not felt by only certain groups and the positive externalities are more evenly distributed.

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APPENDICES

Appendix A: Synopses of Case Studies

1) Biomining:

Biomining is the generic term that describes the processing of metal-containing ores using biological technology. This field is being evaluated by researchers in hope of diminishing the monetary, environmental, and human health hazards associated with precious metal mining. Biomining involving bacteria and other microorganisms is currently being employed in mines around the world including Australia, Chile, Ghana, South Africa, and parts of Central Asia. Reports suggest that the adoption of this technique in industrial production is likely to continue to increase on a global level. Biomining entails two distinct processes: bio-oxidation and bioleaching. Biooxidation is the use of microorganisms to oxidize the mineral matrix in which the target metal is entrapped, thereby opening the structure of the mineral so that it is more easily penetrated by a chemical that will mobilize the target metal. This enriches metals by mobilization and removes metal sulfides from ores that contain precious metals. Bioleaching is the solubilization of metals, most prominently copper, cobalt, nickel, zinc, and uranium. The technique employs manufactured acidophilic bacteria to oxidize metal sulfides. In this process, crushed ore is sprayed with sulfuric acid, which stimulates the growth of manufactured acidophilic bacteria. These bacteria oxidize insoluble metal sulfides like those of copper, nickel, cobalt, and zinc and convert them to soluble metal sulfates. The liquid products comprised of dissolved metals drain to the bottom of the ore heap and may then be subjected to electrolytic processing and converted to pure, solid form.

2) Cyberplasm:

Cyberplasm" is the term dubbed by researchers funded jointly by the National Science Foundation (NSF) and the UK's Engineering and Physical Sciences Research Council (EPSRC) that describes the convergence of synthetic biology, biomimicry, nanotechnology, and robotics to construct a micro-scale robot designed to be capable of sensing and treating pathogens within plants and animals or for other functions involving sensing and remediation (e.g., environmental chemicals). Cyberplasm is a bio-hybrid that integrates engineered bacteria, yeast, and mammalian cells to undertake device-like functions modeled after the sea lamprey. The sea lamprey serves as the model organism to create Cyberplasm as it swims and has a primitive nervous system that is relatively easy to mimic. Biomimetic, synthetic muscles are designed to initiate undulatory movement and propel the robot through water, while synthetic sensors derived from yeast cells report environmental signals. Visual receptors couple the electronics for sensation and actuation through light signals. This combination serves as a basic electronic nervous system. The "electronic brain" signals muscle cells to move. For example, mammalian muscle cells could be used as actuators engineered to have the minimal cellular machinery required for excitation and contraction and are coupled with rhodopin to respond to light. These cells are fueled by microbial cells that produce glucose from environmental chemicals. The muscle cells use the glucose and convert it to ATP in the mitochondria, combining power generation with actuation. Hydrogel is the filler is the material that moves as plasm.

3) De-extinction:

While some synthetic biology projects aim to create new life, others are attempting to bring life back to how it was prior to human involvement. One such technology, titled “de-extinction,” is taking shape through the convergence of disciplines, including synthetic biology, cloning, genetic engineering, and stem cell research. Put simply, de-extinction will recreate endangered and extinct species. Stewart Brand, editor of the Whole Earth Catalog, describes the exigence of the de-extinction plan, noting that “[h] humans have made a huge hole in nature in the last 10,000 years…[and] we have the ability now, and maybe the moral obligation, to repair some of the damage.” The plan of de-extinction technology is two-fold: First, to catalog the genomes of a great host of species around the world, and second, to help restore organisms and habitats damaged or destroyed by human activity. Projects like Genome 10K aim to assemble a genomic zoo—a collection of DNA sequences representing the genomes of 10,000 vertebrate species, approximately one for each vertebrate genus. The project is making use of a variety of technologies, including DNA extraction, amplification and sequencing, phylogenetic and population genetic analysis, and bio-informatics approaches to whole-genome analysis in order to record such genetic diversity with the hope that the catalog will serve as an unprecedented resource for the life sciences and for worldwide conservation efforts.

4) Plant Microbes:

Increasing world populations are leading to a greater need for new and improved food crops. The challenge is how to meet these needs in an environmentally sustainable way. Some experts and technologists are turning to microorganisms as a possible avenue for improving large-scale agriculture. A wide diversity of microorganisms colonize plants. Thousands of microbes can be found living on the stem, leaves, and roots of most plants, and they can also be found within plant's intercellular spaces. These microorganisms can have a profound effect on food crops as microbe interactions can either benefit or harm plants depending on the encounter. For instance, densely colonized soil contains beneficial fungi and rhizobia, which are symbiotically associated with roots and provide plants with mineral nutrients and fixed nitrogen, respectively, in exchange for carbon. By contrast, plants are constantly exposed to a range of fungal, bacterial, and viral pathogens, as well as harsh environmental conditions, and have evolved unique defense mechanisms to fight these infections and events. Some experts and technologists propose to employ techniques from the field of synthetic biology to catalogue and engineer microorganisms with desired characteristics. The proposed engineered microorganisms are designed to manifest a variety of outcomes in food production including improved plant growth, yield, and efficacy, and protection from a variety of plant pathogens and environmental conditions. Developers of the engineered microorganisms claim that their products will be more environmentally friendly than traditional chemical fertilizers and pesticides and that the engineered microorganisms will also reduce the need for soil fertilizers. Current projects are focusing on corn and wheat applications which represent multi-billion dollar markets worldwide.

Appendix B: The Delphi method

Delphi methodology is ideal for small expert populations in order to allow the participants to state their opinions anonymously and without fear of repercussion. Experts participate in the Delphi study on an individual level as well as within their own time frames according to each round. The Delphi method is designed to procedurally blend polling and conferencing by avoiding direct communication between experts. This technique forces delays where experts have time to be reflective on the study's issues while granting the administrators of the study the ability to facilitate the "equal flow of information" to and from all participants as required by the study (see Linstone, 1975, p. 11). An argument for the benefits of this forced delay is that a curbed psychological effect occurs for the participants of the study, and it tends to require less time for observers partaking in the Delphi. This type of methodology assists in maintaining the group dynamics conducive to distilling responses and building toward group consensus. The Delphi method is utilized "when accurate information is unavailable or expensive to obtain, or evaluation models require subjective inputs to the point where they become the dominating parameters" (Linstone & Turoff, 1975). The Delphi method provides an iterative process that calibrates opinions and builds toward consensus through multiple rounds. In a policy Delphi, consensus does not necessarily need to be the endpoint, but rather a revealing of opinions and options could be the ultimate goal (Turoff 2002). The goal for this Delphi study was the latter.

Appendix C: Upstream Oversight Assessment

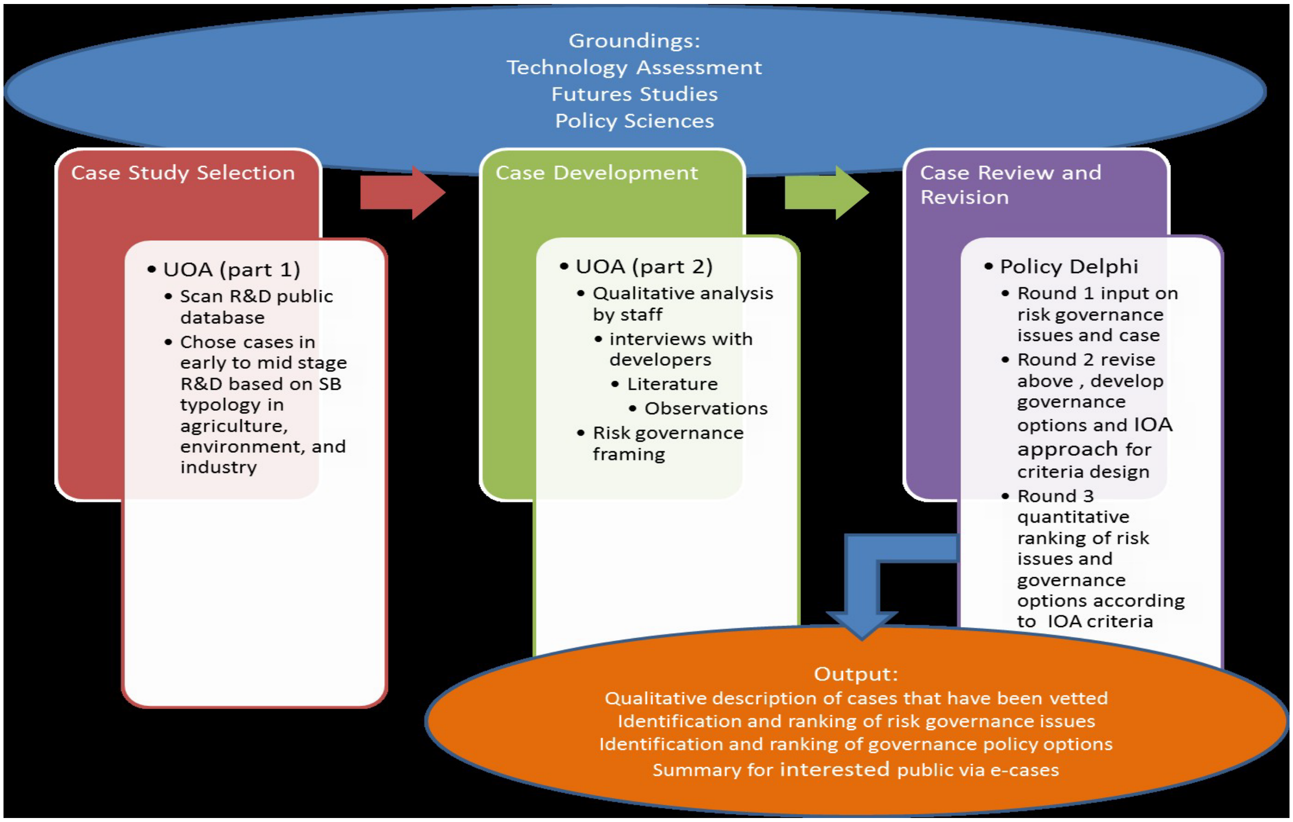

Figure 4: Upstream Oversight Assessment.

Paper 3: Social Capital for the Public. Can Nonprofits Help?

Implications for Non-Profit Organizational Management Research in Science and Technology and Underrepresented Communities

ABSTRACT

People of color and women, especially those living below the poverty line, are less likely to have social capital than their counterparts. Lack of social capital negatively correlates with job promotion, owning homes, financial stability, and inherited social networks. They also have less influence on policy and are less likely to create social mobility for themselves. One of the areas where this lack of social capital becomes evident is in the development and utilization of technological and scientific advances. Specifically, a gap lies between populations that have access to scientific and technological advancements, including but not limited to medical treatments, decision-makers, and information surrounding scientific principles and emerging technology. The development and use of genetically engineered food is one area of science and technology where this gap can be seen. As *nonprofit organizations or non-governmental organizations* (NPOs/NGOs) increasingly provide civic goods and services for underrepresented communities, including addressing hunger and food security, questions arise for social experts and practitioners as to how NPO/NGO management can be more effective in building technology and science social capital within disenfranchised communities of people of color, the poor, and women on an international stage. Social capital theory can be used by NPOs/NGOs as the world of technology and science changes to create and expand their consumers' social capital. This paper uses a small focus group study about knowledge around genetically modified foods within several African American churches in the Wake County area of North Carolina. Its purpose is to garner and generate exploratory information, add to the knowledge, and create best practices in nonprofit organizational research as well an attempt to understand the intersectionality of social capital, nonprofit organizations, and environmental justice issues.

Introduction

Still, in this country, people of color and women, especially those living below the poverty line, are less likely to get hired or promoted in today's job market, own homes, have financial stability and/or financial foundations for future generations, or be able to create social mobility to attain such things. One of the reasons for this is the lack of social capital that these underrepresented groups possess and/or can attain (Cross & Lin 2008; Lin 2000). Other studies also investigate the relationship between minority status and social capital. For example, McGuire (2000) investigates how social capital perpetuates inequalities for racial minorities and women. Burt (2001) looks at how gender moderates the relationship between social capital and mobility.

Social experts need to discover ways to build social capital within these underrepresented groups. The quandary that social experts face is how these associations can be established for these disenfranchised groups. Often, underrepresented groups are serviced, in some way, by multinational, non-governmental, or non-profit organizations (NPOs). The question that arises for many social experts and practitioners engaged in NGO research is how can non-governmental or non-profit management be more effective in building social capital within underrepresented communities on an international stage. NPOs may be able to help close the gap between those who have many choices and those who do not, namely underrepresented communities of women, people of color, and the poor (Cross & Lin 2008; Lin 2008). This may be especially true in today's uncertain times where 1) society is constantly changing due to individual, economic, political, and organizational influences and 2) governmental agencies and programs, such as Social Security, are threatened with becoming incapable of providing the help for which they were created.

One might argue that social capital theory focuses on human agency factors. Some scholars state that recognizing the recursiveness between social structures may be of some importance (Ferguson & Heidemann 2009; Giddens 1987). These authors go on to state that paying attention "specifically to the reciprocal processes by which societal structures influence the activities of individuals and, at the same time, individuals shape their surrounding environment" (Ferguson & Heidemann 2009; Giddens 1979, 1987; Kondrat 2002), may illuminate the relationship agency factors (e.g., personality traits, motivational factors, role perception, stress) and structural factors (e.g., organizational structure, task characteristics, working conditions, logistics, equipment). This kind of analysis could be the key to understanding how NPOs can build social capital in minority communities and among women concerning genetically modified organism research, development, and policies. What factors affect NPOs' ability to build social capital for underrepresented communities? How can those factors be empirically tested? What are the implications of theory to practice for NPOs to build social capital for underrepresented communities as society changes through time and space?

Theory of Social Capital

Throughout social capital theory literature, there lie many definitions. Social capital research moves towards investigating the relational elements as a "source of social action" (Nahapiet & Ghoshal 1998). There have been many distinctions regarding the different levels or kinds of social capital. These definitions attempt to encompass the various resources embedded in the social structure of individuals and organizations. Some define social capital as the skills and resources needed to accomplish some goal and the sense of efficacy enabling these skills and resources. This implies that what is social capital for one purpose may not be for another. Some resources (e.g., money, IQ) may serve more purposes than others. Hepworth & Stitt (2007) define social capital in terms of networks, which are "social relations and interactions among individuals or within groups" (families, organizations, and communities), and norms, which are "established rules of behavior/standards of conduct and shared understandings/values held by a group" (pg. 899). These authors go on to explain how both norms and networks are "embedded in the notion of social structure; networks are characterized by shared norms that encourage social interaction and the development of further networks" (pg. 900). In this paper, social capital, at the individual and organizational level, is defined as in Cross and Lin's (2008) definition as "*resources embedded in a social structure that are accessed and/or mobilized in purposive actions*" (pg. 365).

There are some benefits to acquiring social capital. Putman (1993) and many other social capital theorists like Coleman (1988), Hepworth & Stitt (2007), and Leana & van Buren (1999) have studied and identified the benefits of attaining social capital. Attaining social capital allows individuals and organizations to resolve collective problems more easily, ensures that people do not opt out of their responsibilities, and increases associability (Putnam 1993). Hempworth & Stitt (2007) states that attaining social capital assists in facilitating individuals and organizations to become more trusting and trustworthy in areas where they have repeated interactions with other individuals and organizations. Leana & van Buren (1999) states that attaining social capital improves individual and organizational survivability by enabling connections with others, thereby increasing the development of individuals and organizations. This is manifested through changes in norms, rules, resources, or even the definition of resources. Agranoff & McGuire 2001 states that attaining social capital can serve as a channel for information, leading to decision-making power, power to organize and mobilize, and the ability to exercise influence or authorize action, which is paramount to implementation. In management, Borgatti & Foster

(2003) state that social capital brings together related positions and helps build power, leadership, mobility, and employment opportunities, increases individual performance and creativity, entrepreneurship and team performance. Schneider (2009) states that attaining social capital serves as a psychological buffer that allows individuals and organizations to better cope with traumas, environmental shocks, changes in needs, or circumstances that alter through time and space.

Individual Social Capital and Technology and Science

As there are many definitions of social capital, there are many forms of individual social capital, some of which are discussed below. Yet, there is another distinction to address within individual social capital first. Many theorists in social capital theory attempt to distinguish between personal social capital (one's circle of family, friends, and communities) and professional social capital (ability to obtain employment, acceptance into professional organizations that increase network capital, etc.). Although this discussion on social capital has been part of a long-term debate, the researcher argues that although these social capital affect each other, they are different and may be distinguished. Still, they are connected so that they cannot truly be separated. Social capital in one's work life also affects one's personal life and vice versa. Social circles may assist in building one's ability to gain higher employment levels. Obtaining higher levels of employment through higher levels of education, for example, may lead to including friends and acquaintances, even marriages (Lai 2008). Attaining social capital through professional means or purely social or personal means can affect one's entire life.

Reasons to highlight how this might affect underrepresented communities are brought to light in studies by Lin (2000) and Cross & Lin (2008). Cross & Lin conducted a survey in 2008 that examined the relationship between access to social capital and status attainment. The results "confirmed that people mainly associate with others belonging to the same social group." They also confirm that "racial/ethnic divides are among the strongest in our society" (McPherson, et. al., 2001; Cross & Lin 2008). Cross & Lin go on to propose that "the problem with this, particularly related to status attainment, is that minorities have historically lower status positions relative to whites. If minorities are predominantly associated with ties in lower statuses, their social capital cannot provide them with the information and influence necessary to 'become upwardly socially mobile'" (Cross & Lin 2008; Lin 2000).

Hepworth & Stitt (2007) and Coleman (1988) discuss items that are separate forms of social capital. One form of social capital is economic capital. Economic capital can be acquired through access to employment income or financial loans. Another type of social capital can be expressed as physical capital: access to adequate housing, transportation infrastructures, and food and medical needs. Human capital describes possessing knowledge and skills deemed necessary in a given society. Cultural capital denotes characteristics and skills that are culturally valued within a given culture or subculture of society. It is argued that these forms of social capital collectively comprise a model of social capital components. Although each of these kinds of capital has legitimate properties separately, only in their totality do they encompass the actual depth of social capital (Nahapiet & Ghoshal 1998). Instead of seeing them as separate components, this paper assumes that the interconnectedness of each definition of social capital leads and is related to the following form. This paper makes the following assumptions concerning how these different levels of individual social capital are related.

Economic capital is more than just actually *having money*. Its properties are more concerned with the ability to *access financial means.* Therefore, an NPO that serves first-time bank account holders or teaches financial literacy is establishing access to economic means instead of the actual money itself. NPOs that provide classes on interview skills and connections to interviews or job fairs are giving access to the job market by increasing the soft skills needed to obtain employment. Economic capital, or the ability to attain a job, get a loan, and access other forms of funding (scholarships, fellowships, etc.), leads to access physical capital or access to housing and transportation. Those who can acquire an adequate job or funding source to meet their needs are often afforded access to sufficient and appropriate housing and transportation, i.e., "*Because of this new job, I can afford a bigger, safer home for my family*." Economic capital can lead to human capital as well as better networks.

Human capital, defined as possessing knowledge and skills deemed necessary in a given society, may give an individual the legitimacy needed to attain social mobility (Hepworth & Stitt, 2007; Lin & Erickson, 2008). Legitimacy can facilitate the translation of social capital into many forms of goal achievement, such as the goal of social mobility. Legitimacy provides a basis for evaluating the "unknown," a way of validation for taking a risk or a chance on a relatively unknown element, i.e., using resumes. The higher the perceived legitimacy, the better the evaluation of the unknown, and the more likely risk adversity decreases, which, in turn, increases the job competitiveness of the individual. Many studies have highlighted human capital components, emphasizing that "the relevant characteristics of human capital are education, experience, and knowledge," which allows "access to a broader range of opportunities" (Felicio et al., 2014; Writh et al., 1995; Davidsson & Honig 2003; Gimeno et al., 1997). A higher level of education is positively related to performance" in personal and work lives (Felicio et al., 2014; Cooper et al., 1994; Gimeno et al., 1997). This social capital includes education level, technical and industrial certifications or licenses, and acquisition of new skills, i.e., computer skills or experience with new software. Although not in all cases, human capital can lead to economic capital, which provides the basis for access to physical capital. The distribution of wealth and income can partially be explained by education.

Networks are already accepted as an essential way to build individual social capital. The famous statement highlights this, "*It's who you know, not always what you know and who they know*." One of the reasons that education and human capital are far from accounting for economic capital is networks. Network capital for individuals is closely related to the acquisition of the power to influence, and having power and position may significantly affect the networks of which an individual and an organization are a part. Networks can create power for two reasons. The first reason is that network capital leads to the power of information. A member with access to information in an individual's network can lead to more information sharing with that individual, which, in turn, leads to more opportunities to expand one's social capital. The second reason is that network capital leads to decision-making power. Having access to a person with the power to "exercise influence or authorize action" (Agranoff & McGuire 2001) means that one can utilize their network to acquire and access resources needed to expand other components of their social capital. Agranoff & McGuire (2001) and Gray (1999) portray this collaboration sequence as a form of power-sharing. They contend that "power sharing implies at least a temporary redistribution of power, enabling stakeholders with differential power levels to engage in domain transformation control of information, influence or authorize action" (pg. 316). This transfer allows individuals needing social capital to access different power levels without having to have much power themselves.

When discussing power, it is essential to examine which dimensions of power are in play. Intuitively, individuals in need of social capital do not have power over most of what is needed to attain social capital. They do not have power over the resources or the rules to access them.

This implies that network capital should lead to acquiring power rather than *power over it*. Agranoff & McGuire (2001) state that "this is a *power to* that, under many conditions of ultra-complexity, characterizes situations better than *power over*" (pg. 316). Although they discussed organizational networks, the researcher would argue that this also applies to individual network capital. The power of information sharing and access to those who have the power to make decisions, influence, and authorize action leads to the power of the individual. In other words, networks can increase an individual's *power to* be considered for a position in a prestigious training or fellowship; an invitation from a social network member to a work or social event that puts an individual in contact with others increases the individual's *power to* more information, the *power to* be recommended, and the *power to* expand the network itself, etc. Types of network members that would be able to provide the power to information and/or the power to make decisions would be those that hold supervisory and management positions and/or human resource positions, those that have connections to professional or voluntary associations, i.e., a retired person who is a member of the local rotary, etc.

From this discussion, individual social capital can be measured through constructs that capture networks, specifically, constructs that capture the power dynamics that result from networks in the form of information sharing and decision-making power; legitimacy, which is the increase or decrease in job competitiveness, and economic capital which is access to funding, or jobs. Fruitful linkages emerged as the researcher grew more knowledgeable about social capital theory. Since social capital is defined as resources and norms embedded in the social structure accessed by purposive action, the question of how to access these embedded resources or how to change the norms and rules surrounding them to be more easily accessed must be addressed. *Resources* (a concept shared by both theories) are the components of social capital (legitimacy, funding, networks, and power) embedded within the social structure. *Rules or the norms* (found in both theories) can, in essence, be seen as access to those components, i.e., who is allowed access and who is not. Essentially, NPOs shape societal structures by building social capital for the underrepresented groups that they serve, who, in turn, act as individual actors shaping society's rules about who gets access to the resources. Schneider (2006) stated that "social relationships and patterns of trust (social capital) that enable people to gain access to resources like government services, organization funding, and jobs are crucial in helping families achieve their goals" (pg. 243). Those goals often include increasing some components of their social capital.

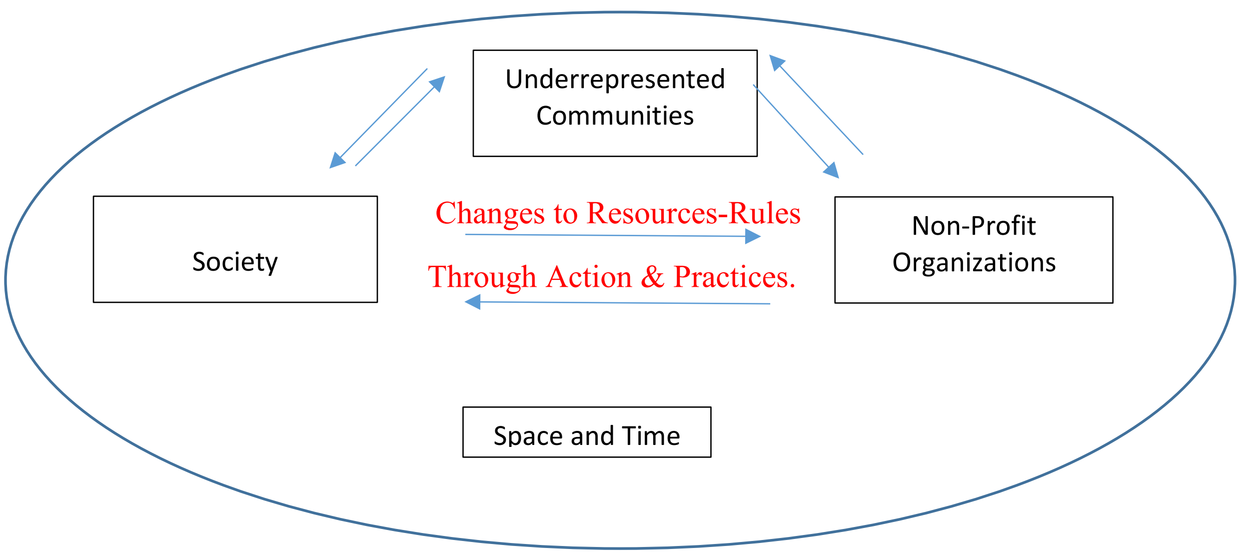

Figure 1: Recursive Process.

Figure 1 depicts a model of the recursive process by which each group influences the other. Each box acts as the actors by which their practices influence each other and society. Society is simultaneously shaping and influencing NPOs and individuals of underrepresented communities. All three of these boxes are in a state of constant change for various reasons. Since their interaction is inevitable, it stands to reason that these three groups will continuously shape each other concurrently. This interaction is dictated by the production of new practices and the reproduction of those practices that increase the social capital of the underrepresented groups. Increasing this social capital also facilitates the recursive process with society and underrepresented communities. Underrepresented communities can shape the society they live in with increased social capital. NPOs are in a recursive relationship with society as both shape each other. For instance, society can shape how organizations attain legitimacy through isomorphism or institutional practices such as mimetic isomorphism. Mimetic isomorphism results from standard responses to uncertainty. These uncertainties can manifest as poorly understood organizational technologies, ambiguous goals, or environmental symbolic uncertainty created when organizations model themselves on other organizations. Organizations tend to model themselves after similar organizations in their field that they perceive to be more legitimate or successful (DiMaggio & Powell 1983). In turn, non-profit and non-governmental organizations' "interactions with multinational corporations and national governments impact the global social and moral organizational culture of multinational enterprises" (Teegen, Doh & Vachani 2004).

A Case Study:

Focus Groups in the African American Church Community on Genetically Modified Food:

A small exploratory focus analysis was conducted in some churches of Wake County, where their thoughts on genetically modified foods were explored. The study population recruits church members where known food deserts exist. Food desert communities are often underrepresented communities. While it is not intentional that the study recruits vulnerable populations, they will likely be invited to participate in the focus group sessions because of their place of worship. However, our invitation letter, informed consent, and research questions will be written in lay language. In addition, all documents were read to recruited subjects before an informed consent signature was requested. Highlighting support capital versus leverage capital, Figure 1 displays the macro-level data obtained, including the proximity of each church to a food desert in 2010 and 2015. A food desert is an area with limited access to affordable and nutritious food. Most of these churches were in areas of town that indicated low access and low income in all four proximity conditions in both 2010 and 2015. Mostly, these conditions did not change or improve within the 5 years this analysis was completed. Many of these churches had kitchens and kitchen ministries that may have provided "support capital." Still, the conditions could have changed their "life circumstances" or increased their congregation's "leverage capital," namely increasing their access to nutritious and affordable food options did not change.

Table 1: Food Desert Analysis.

	Name of Church	**Compassionate Tabernacle**	**Juniper Level**	**Mt. Vernon**	**Oak City**	**Pleasant Grove**	**St. Augusta**	**Stokes Chapel**
Social Capital Components								
Location		2310 Compassionate Dr. Raleigh, NC 27610	9104 Sauls Rd, Raleigh, NC 27603	301 N. Lombard St, Clayton, NC 27520	726 Method Rd. Raleigh 27607	1538 Davis Dr. Cary, NC 27519; P.O. Box 3603 Cary, NC 27519	605 Bridge St. Fuquay-Varina, NC 27526; P.O. Box 836 Fuquay-Varina, NC 27526	6715 Massey Rd. Zebulon, NC 27597 P.O. Box 478 Zebulon, NC 27597
Proximity to Food Desert Conditions LI Low Income LA Low Access (0 yes, 1 no) (https://www.ers.usda.gov/data-products/food-access-research-atlas/go-to-the-atlas/)								
Low Income & Access Layers 2015, 2010								
LI and LA at 1 and 10 miles		1, 1	1,1	1,0	1,1	1, 1	1, 1	1, 1
LI and LA at 1/2 and 10 miles		0,0	1,1	0,0	0,0	0,0	1, 1	1, 1
LI and LA at 1 and 20 miles		1, 1	1,1	0,0	1,1	1, 1	1, 1	1, 1
LI and LA using vehicle access		0,0	1,1	0,0	1,1	1, 1	1, 1	0,0
Component Layers 2015 (0 yes, 1 no)								
Low Income		0,0	1,1	0,0	0,0	0,0	1, 1	0,0
Low Access at 1 and 10 miles		1, 1	0,0	1,0	1,1	0,0	0,0	0,0
Low Access at 1/2 and 10 miles		0,0	0,0	1, 1	0,0	0,0	0,0	0,0
Low Access at 1 and 20 miles		1, 1	0,0	0,0	1,1	0,0	0,0	0,0
Low vehicle access		0,0	1,1	0,0	1,1	1, 1	0,0	0,0
High group quarters		1, 1	1,1	0,0	0,0	0,0	1, 1	1, 1

Although this focus group is small which can affect generalization, it is significant because it adds to the basis of exploration and empirical studies within the African American community regarding genetically engineered foods and the role of non-profit organizations. The focus group pilot study consisted of a non-experimental design. This pilot study comprised 65 “focus group” participants within 7 African American churches in Wake County, North Carolina. Using a faith-based approach, the research team conducted a descriptive study embracing faith-based leaders and exploring factors that influence them and their congregation's perceptions regarding genetically modified foods, especially in communities where known food deserts exist (Hotz & Mathews, 2012). Prior research involving faith-based leaders in underrepresented communities shows a strong correlation between church leadership and congregation perceptions. Faith-based leaders often act as cultural brokers for minority communities (Bronheim, 2001). Faith-based leaders may influence the congregation’s perceptions of risk and trust in science when selecting genetically modified foods. In doing so, consumer acceptance of GM foods may be improved.

Participants in this study were recruited via a snowball sampling process. An initial presentation regarding the project was held for the pastors of the Wake Missionary Baptist Association, Inc. Pastors were invited to participate and recruit church members for this study. Follow-up with each pastor was conducted by contacting the secretary and pastor of each church in the Wake Missionary Baptist Association, Inc., and providing them with an informational flyer about the study. These individuals asked their congregation if they would like to participate, and individuals signed up accordingly. The participants were asked about awareness, food safety, trust, choice & social capital. The perceived risks and benefits of producing and consuming genetically modified food are under-researched among racial/ethnic and cultural groups. Cultural attitudes toward genetic engineering affect persistent food skepticism and may lead to scientific mistrust regarding genetically modified food produced in the United States and exported to foreign countries (Ludlow &Smyth, 2011; Banati and Szabos, 2006). Several research studies confirm that consumer awareness and attitudes influence consumer behavior toward GM food supply and may lead to strong preferences for non-GM products (Baker and Burnham, 2001; Li et al. 2004). The cultural cognition of underrepresented groups and how cultural groups are exposed to information influences cultural views on the risks and benefits of a GM food supply (Kahan, D. M., Braman, D., Slovic, P., Gastil, J. and Cohen, G., 2008).

Data for this study was gathered through seven focus groups. Each focus group took approximately three hours. The first half hour of the focus group was spent explaining the studies' goals and objectives, explaining participant's rights, and obtaining informed consent. Next, participants were given a demographic survey to collect by the session's end. Then, the investigators reviewed the guiding questions until the end of the session. The focus group sessions will be recorded using a digital audio recorder. The researchers used a transcription service by Rev.com to convert the audiotaped session into text. In the transcript process, client information was confidential, and the service provided a non-disclosure agreement. The focus group was completed when each demographic survey was collected. Each focus group participant will be given a random research number. Participants were asked to use their number during the sessions when responding to questions. Therefore, research numbers were used as the primary identifier in transcribed notes and demographic surveys.

Only the data generated from the social capital questions was explored for this study. Since the data collection format was a focus group setting, the researchers used 4-7 questions to capture concepts, including the concept of social capital. The goal was to see the participants' thoughts about their churches' (NPOs) relationship with building social capital surrounding genetically modified food (science/technology). The questions were asked at each church or site, and the resulting data are categorized at the individual level and group level (although the group level data, compared from church to church, is minimally included in this analysis: see limitations). Through the focus group, two types of capital were explored in a normative model: network capital and human capital. The questions asked were:

1) If the participants thought that churches should educate their congregation on food safety and health of emerging food technologies (human capital 1);
2) If churches should advocate for their congregation concerning food technologies (network capital);
3) If religious entities are obligated to educate their congregation members regarding food technologies (human2/network);
4) If they trusted their pastor the most to tell the congregation members the truth about genetically modified food.

Results

The questions were presented in a normative model ("should") to explore the "responsibility" of the nonprofit organization from the point of view of the participants. Qualitative and descriptive analysis was used to assess consumer perceptions and risks and explore cultural strategies to increase consumer trust. Using word clouds for data visualization and a qualitative data analysis program to identify themes from the focus groups, the research team coded and analyzed the transcripts from the focus group sessions conducted in North Carolina. Reports will include aggregate data; however, individual responses will be used to underscore themes that arise from the pilot sessions. Table 2 below displays the raw numbers from the study of how the focus group responded to the questions.

Table 2: Raw group data from responses to social capital questions.

	Question 1	Question 2	Question 3	Question: TRUST PASTOR
YES	**89.2% 58**	**61.5% 40**	**69.2% 45**	**47.7% 31**
NO	**3.1% 2**	**9.2% 6**	**20% 13**	**40% 26**
UNSURE	**7.7% 5**	**29.2% 19**	**10.8% 7**	**12.3% 8**

Most participants (89.2%) thought churches should educate their congregation on food safety and health regarding emerging food technologies, with only 3.1% disagreeing (the remainder were unsure). The sentiment is evident in the participants' statements: *"…but our body is the temple, so we need to have it clean. So if we're educated more about how to eat, I think it will work." "I believe that if we administer to the whole man, then part of administering to the whole man is how to live a healthier life."* Outcomes like health were at the top of the concerns in this small study. This answer also highlighted that the type of nonprofit organization, i.e. its beliefs or perceived purpose, may have an influence on the roles and responsibilities of the organization. That influence is vital to note for each nonprofit organization, as it may be utilized to find ways to adapt to the needs of its population. *"If we're our brother's keeper, then we must take care of one another." "If we're not healthy we're not good for ministry. We can't do ministry if we are not healthy. We don't want to go, we're tired or whatever. So I think that's a part of it too, being physically able and active."*

The implications of these answers highlight that the public here thinks that nonprofit organizations should increase the human capital of its constituents, in this case, congregants. They can do this by increasing education of its congregants and by association, public outreach efforts. *"That's why all the churches should join the EMA [Evangelical Ministerial Association] because they do a lot to educate the other pastors so that they can pass this information on."*

A large percentage of the participants were unsure as to what role the church should play in advocacy demonstrated by their uncertainty while 61.5% of the participants thought that churches should advocate for their congregation concerning these technologies. These sentiments were captured in the following statements. *"…the church to me is about worshipping God, worshipping the Lord. If you teach stuff about that stuff but ultimately go out and take a position on things, I think it takes away from worshipping the Lord. That's just my position. I'm not saying we shouldn't talk about [it] if we do it one-on-one but we have to survey or something … That's just … to me, is okay. To make anything that takes away from worshipping and doing the work of the Lord, I think I'm against."*

Advocacy, in the opinion of the congregants, can lead to a better lifestyle, assists with socio-economic issues, more educated population, and more information about the technology used in daily life. *…Should the church advocate for - I think that the church should advocate, not that they have to, but they should advocate a better way of life for individuals, whether it be spiritual, whether it be natural or emotional, financial or whatever. I think the church should be all about giving information that will enhance a person's lifestyle." "I think the church should be more about advocating and organizing these people for the socio-economic problems. They can give you the information but at the end of the day, you're still going to walk out that door and it's up to you economically you can afford what they're telling you."*

The implications of this answer highlight that a large percentage public here thinks that nonprofit organizations should increase the network capital of its constituents, in this case congregants.

Almost 70% of the participants thought that churches had an obligation to educate their congregations on genetically modified foods, but only 6.2% of the participants trusted their pastor the most (out of doctors, independent experts/researchers, government, supermarkets, or farmers). One participant stated *"If most people come to the church for food for thought for [the] religious aspect, I think the church, I'm not going to say they should. They should, right? That they have to, but it is a good thing because the politicians run over here for the votes, so a lot of people get things from the church. They would never know unless they came to church to find out."* The implications of this answer highlight that this public thinks that nonprofit organizations should continue to increase the human capital of its constituents, in this case congregants, through education about genetically modified foods. This answer highlights how the congregants realize many of the critical factors, and stakeholders are outside of who grows the food product. There are political and social implications as well that different types of publics have a high level of interaction with.

When asked if the participants would trust the pastor to tell them the "real" risks associated with genetically modified food, the results were surprisingly similar, with 47.7% trusting the pastor, 40% not trusting their religious leaders, and 12.3% responding that they were unsure. "*I think you should, but you've got to get somebody who is qualified. You just can't get somebody with glaucoma to do the job."* They also talked about how the doctor has the freedom to ask questions directly about your health, as that is a physician's purpose, but that does not mean physicians ask about 'genetically modified food' in a checkup. *"Most doctors will say to you when you go, you need to lose a little weight, you need to, what you are eating…They'll give you some handouts. Maybe you should cut back on this and eat some of that. I think most doctors do; once they notice your health, if you have a health issue, they give you some insight. Yeah, they* *give you a paper and tell you, why don't you pay attention to this. They can't enforce it because when you leave, you're on your own, it's what you do. Basically, like I said, some doctors tell and some don't. Some want you to keep coming back because the medical company is paying them too."*

"I think it's sometimes how they state it, too. Sometimes, they may talk about staying away from processed foods, processed meats, or whatever because they're high in salt. As far as coming out and saying genetically modified, I never heard that term."

They highlighted what is affordable versus what is healthy, as well as the lack of influence a physician has on the financial situation of a family or person. *"Yeah, I think doctors are just kind of in the same place as the church. He's in a rock and a hard place. When I take my children to get physicals, the doctor asks the following questions: How are they eating? Are they eating well? Are they eating from the daily groups? Are they getting enough bread? Are they getting enough dairy? Are they getting enough of this? Are they eating enough fruit and vegetables? I [will] be honest, I said, well yeah, but then… [there are] some days where it's cheaper, and it's easier for us to get off the $1 menu. The only… [thing] that the doctor can do, because she can't fix our economic problem, is say, okay, and on to the next question."*

In this answer, the congregants mentioned that qualifications in a profession were essential to who they trusted.

Discussion

The pattern throughout these answers and quotes from the participants suggests adaptability is needed for a nonprofit organization. From the above discussion, some implications can be made to predict which NPOs are providing social capital for the underrepresented communities they serve, as well as implications for how non-profit management can be more conducive to affecting the individual social capital of these populations. This implies that an organization that attempts to raise the social capital of underrepresented populations needs to be able to adapt to the time and space in which the society it serves is currently, as well as be able to anticipate and adapt to how the society will change from the influence of its actors. Adaptability will allow the NPOs to meet the ever-changing needs of society and these target populations. NPOs that can create and reproduce programs responsive to environmental inputs (society) and the needs of the target populations will be able to provide and increase social capital components of the underrepresented communities they serve. For example, in 2008, the economy bottomed out, and obtaining jobs became the focus of many American families (in other words, securing funding). Many community colleges' human resource departments created systems allowing access to new job training and work skill-related programs to specifically address these needs. These latest job training classes (legitimacy) provided the ability for these displaced workers to obtain new skills needed for their jobs, attaining competitiveness and staying current and relevant. New skills also present the possibility of applying to new positions, so the college hosted computer classes to teach current and relative technical skills on trend with the changing workforce environment.

Having social capital often benefits the NPO's adaptability. Leana and van Buren (1999) deduced from their model of organizational social capital that "social capital can facilitate flexibility rather than rigidity in the ways work is organized and carried out" (pg. 548). Organizations high in social capital are allowed flexibility and attain more legitimacy and funding, which in turn leads to more survivability. This allows more individuals of underrepresented communities to be served, increasing NPOs and individual effects on societal forces. In this case, participants called for their organization (the church) to adapt to the education needs of the population they serve, adapt to the advocacy needs of the population they serve, and adapt to meeting the needs of the population they serve in order to increase trust.

There are three reasons why this kind of study might be necessary for non-profit management. First, NPOs are increasingly becoming organizations that provide civic goods and services essential for many people to function in today's society, especially women, people of color, and people experiencing poverty. Increasingly, these civic organizations are associated with social capital degradation. Wacquant (1998) highlights this focusing on Pierre Bourdieu's concept of social capital, stating "the formal organizations are presumed to provide civic goods and services (physical safety, legal protection, welfare, education, housing, and health care), but these institutions have become the cause of degradation of social capital for underrepresented communities" (Wacquant, 1998; Bourdieu, 1985; 1986). He proposes that these institutions have turned into "instruments of surveillance, suspicion, and exclusion rather than vehicles of social integration and trust-building" (Pg. 26).

Second, because NPOs distribute civic goods and services, they have a unique position in society. Their perpetual interactions with underrepresented populations may prove to be a source of social capital for these communities. When economic forces bring government austerity, threaten social resources and benefits, and disrupt the distributive patterns of these social services, non-profits serve more and more of the population. More NPOs are operating globally and being contracted to provide governmental services.

Cross & Lin (2008) state that "associationism and cognate forms of sociability generate social capital by the mere fact that people interact face-to-face, irrespective of their primary goals or instrumental interests (pg. 243)." Leana & van Buren (1999) describe associationism as a subordination of individual goals to a collective one. Organizations providing opportunities for individuals to participate are critical to making it possible for NPOs to assist underrepresented communities in accessing the resources embedded in the social structure that are needed to increase social capital. These interactions that serve as a possible source of social capital can also be adapted to strategically and continuously meet the needs of these underrepresented groups, which are in constant change as well.

There is one final reason why it is crucial to examine how non-profit management can be more conducive to enhancing the social capital of those they serve. NPOs often start with an excellent strategy to address the needs of a target population but frequently end up focusing on the early outcomes and processes. In other words, NPOs often end up focusing on the process of delivering services to achieve efficiency and/or effectiveness standards instead of strategically addressing the needs of the target populations they set out to help have better lives (Benevene and Cortini, 2010). This focus on efficiency and effectiveness often undercuts the ability for organizations to attain the knowledge necessary to strategically and continuously meet the changing needs of these target populations. Benevene and Cortini (2001) develop their theoretical basis by forming their study around how NPO cultures are…

> “naturally action-oriented: the reason why a NPO starts its activities is to meet the specific needs of a targeted group of people, but given their limited resources, the organizational culture of most NPOs are built almost exclusively around delivering services and not addressing strategic issues. This might seriously hinder the development of knowledge due to the fact that they focus on efficacy and efficiency of the services and not on knowledge. Being adaptable and responsive to the environmental inputs is not sufficient to generate knowledge. Organizations should rather be able to generate

knowledge through the interpretation of environment signals. NPOs must not only learn but should also drop outdated knowledge" (pg. 125-126).

These environmental signals are the changes in the needs of the target populations they set out to address. The researcher speculates, that society, disenfranchised populations, and NPOs inevitably affect one another in a recursive process, that NPOs can acquire this new knowledge by focusing, not only on delivering services but by ensuring those services are created around building social capital for those they serve. This new knowledge may allow NPOs to be efficient and effective towards establishing the social capital of underrepresented communities, both in functional and dysfunctional ways.

Focusing on social capital for the target populations also ensures that the NPO is meeting the needs of the population they serve, in real-time. Adequately meeting the needs of a NPOs' target population is a big debate in the non-profit community, especially among consumers and practitioners. The growing attitude concerning service organizations is that they are in the business of repeat customers. Service organizational goals are not geared toward serving the consumer in such a way that they gain social mobility or social capital—it is to ensure that they have just enough to get by with their current circumstances. This model of service delivery allows for a recurring circle of continued care instead of providing a means where skills are built and utilized to build social capital, and therefore, social mobility. This model of service delivery also denies other consumers assistance because of the dependence factor the model builds. The literature calls this support capital, a type of social capital that attempts to help individuals deal with their current circumstances versus leverage capital, which allows individuals to "change their life circumstances and take advantage of opportunities" (Hepworth & Stitt 2007, pg. 898).

Organizational social capital may be beneficial for an NPO to attain, as the more organizational social capital an NPO obtains, the better position an NPO would be to meet the needs of the target population and deal with differing and changing societal influences. The benefits of NPOs acquiring organizational social capital encompass "the context, stock of relationships, interpersonal trust, and norms that allow certain behaviors and relationships between individuals, and that ensure conditions for the development of organizations and knowledge sharing" (Agranoff & McGuire 2001 pg. 316). NPOs may be able to use their social capital to access the information needed to address the social capital needs of the target populations they set out to serve strategically.

Limitations to the Study

A small sample has its own set of limitations for predicting and generalizations of populations, both at the micro and macro levels. This case study was a pilot study that only encompassed 7 churches, an individual sample of (65 + 7 pastors) people. The sample is not considered random because it was collected via a snowball sampling. Therefore, it cannot be generalizable. However, the goal of this study was to analyze a specific portion of the population. Therefore, it could never be randomized.

There are many "best fit" organizational models because each organization has unique needs, stakeholders, and populations they serve. Another limitation of this study is the lack of longevity in the analysis. The researcher's goal is to add to the knowledge base that NPOs can use to design themselves to be able to create social capital instead of just "filling in the gaps" to provide sustainability instead of prosperity. The main premise of this paper builds on the notion that organizational adaptability and organizational social capital are key elements for NPOs to be able to build social capital for these populations.

Another limitation to the focus group study was being able to obtain the information on a macro level from the nonprofit organizations, i.e. the churches. Since churches are not required to file taxes with the federal government, many of them were reluctant to release their financial information for analysis and comparison, even being used anomalously.

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APPENDICES

Appendix A: Demographic Data of the Participants

Tables 3-6 display descriptive statistics on the gender, marital status, age, and educational level of the study participants.

Table 3: GENDER.

	FREQUENCY	PERCENT	VALID PERCENT	CUMULATIVE PERCENT
FEMALE	45	69.2	69.2	69.2
MALE	20	30.8	30.8	100
TOTAL	65	100	100	

Table 4: MARITAL STATUS.

	FREQUENCY	PERCENT	VALID PERCENT	CUMULATIVE PERCENT
DIVORCED	12	18.5	18.5	18.5
MARRIED	36	55.4	55.4	73.9
SINGLE	9	13.8	13.8	87.7
WIDOWED	8	12.3	12.3	100
TOTAL	65	100	100	

Table 5: AGE.

MEAN	MEDIAN	ST. DEV	RANGE	MINIMUM	MAXIMUM	N
55.35	58	13.020	60	19	79	63

Table 6: EDUCATION LEVEL.

	FREQUENCY	PERCENT	VALID PERCENT	CUMULATIVE PERCENT
FOUR-YEAR COLLEGE DEGREE	19	29.2	29.2	29.2
HIGH SCHOOL DIPLOMA	11	16.9	16.9	46.1
LESS THAN HIGH SCHOOL	2	3.1	3.1	49.2
LESS THAN HIGH SCHOOL, SOME COLLEGE	1	1.5	1.5	50.7
POSTGRADUATE	12	18.5	18.6	69.3
SOME COLLEGE	19	29.2	29.2	98.5
SOME COLLEGE (SOC DEGREE)	1	1.5	1.5	100
TOTAL	65	100	100	

Appendix B: Focus Group Guiding Questions

Guiding Focus Group Questions

<u>Working Definitions:</u>
Genetically Modified Food:
Organic Foods:
<u>Awareness Questions:</u>
How much have you heard or read about Genetic Modification of Foods?
Nothing at all___ Not Much___ Some___ A Great Deal______ DK/Refused_____
Before this focus group, have you ever discussed genetic modification of foods with anyone?
Frequently________ Occasionally_________ Only Once/Twice_________
Have you ever eaten any GM Food? Yes/No If so, what?
Are you aware that GMO foods are currently for sale in the supermarket?
Will genetic modification improve the quality of life for people like you?

<u>Food Safety Questions</u>
Do you eat GMO foods from plants or animals like (corn, soy, tomatoes, wheat, nectarines, grapes, dairy, salmon)? Yes/No
Do you think GM foods are safe? Yes/No
How do you know they are safe?
Do you think genetically modified foods are hazardous to your health? Yes/No
How do you know that GM foods are hazardous to you? (Please specify source)
Do you think GMO foods are hazardous to the environment? Yes/No
How do you know that GM foods are dangerous to the environment?
Are there benefits to your health when you eat GM foods? Yes/No If so, what are those benefits?
How do you know that GM foods are beneficial to you? (Please specify source)
If our food industry genetically modifies our food, do you think our food labels should reveal the modification? Yes/No
If GMO labeling is mandatory, would you read it? Yes/No
Do you currently read labels? Yes/No
Do you know if you're buying genetically modified food? Yes/No
Would you buy it if you knew that it was a GM food? Yes/No

<u>Trust (Credibility) Questions</u>
Who would you trust to tell you about genetically modified food's "real" risks and benefits?

- Would you trust your doctor? Yes/No
- Would you trust your pastor? Yes/No
- Would you trust the government (like the FDA)? Yes/No
- Would you trust an independent researcher? Yes/No
- Would you trust the supermarket? Yes/No

- Would you trust the local farmer? Yes/No
- Other(s)

<u>Choice Questions</u>

Does your supermarket offer non-GMO food products? Yes/No
Would you prefer non-GMO products over GMO products? Yes/No
What if they cost the same amount? Yes/No
Would you be willing to pay more for non-GMO products? Yes/No

<u>Social Capital Questions</u>

Should the church educate its congregation on food health and safety?
Do you believe a religious entity is obligated to educate its congregation?
Are they expected to act to benefit citizens where GMOs are concerned?
How did you learn about GMOs?
Who do you trust most to tell you the truth about GMO food?
Doctors____ Experts____ Friends____ Family____ Church____ Other_____

<u>Organic Food Questions</u>

Do you eat organic foods?
Have you ever heard of the “Dirty Dozen” list by the Environmental Working Group (EWG)?
Have you ever heard of the “Clean Fifteen”?

Dissertation Conclusion

It is important to remember that "emerging technologies" can encompass so much across many different fields. Each technology has its own set of positive and negative externalities that lead to various environmental justice issues, so narrowing down each attempted research question and the subject is necessary to determine how to address the environmental justice issues presented by the societal introduction of the said technology. Thus, this dissertation uses these case studies to explore the diversity of the problems associated with technology adoption, environmental justice issues, and the public's role in technology governance.

It is essential to reassess best practices for including the public in decision-making and address potential environmental justice issues within the scope of emerging technologies. Experts' attitudes about the public's role in science and technology research and development may facilitate or inhibit these practices, as experts are usually the stakeholder group with the most power in developing and implementing the technologies within society. Historically, experts have had a lot of energy in the science and technology policy system and, therefore, can facilitate or prevent public participation. They develop the technology, serve on expert committees that make recommendations, generate the data for regulatory approval, and have close relationships with regulators. The deficit model of public participation gives experts much power, and subsequently, experts resist public participation due to the desire to maintain that power. Thus, examining these attitudes is essential (Mangset, Engelstad, Teigen, and Gulbrandsen, 2019).

Exploring environmental justice issues as technology emerges, as opposed to addressing the effects after said technology is embedded into a social system, as is the current state of environmental justice initiatives, may decrease the negative impacts of developing emerging technologies on disparaged and disadvantaged populations and communities. This said technology is usually already embedded economically into the social system before the environmental justice issues are addressed. This embeddedness facilitates a situation where populations may not receive the benefits associated with the technology, as their concerns were not discussed or even ignored at the time of development and/or implementation.

This research was conducted to explore environmental justice issues as they relate to specific emerging technologies that are in some level of development. The technologies within this research project, synthetic biology, and agricultural transgenic pests, are not yet embedded in the current social and economic systems or have a popular response in opposition to complete embeddedness within those systems as development is occurring now, such as genetically modified food. One way to explore these issues is to create a system in which environmental justice issues can be explored scientifically and scholarly, as the technology is in its developmental stages, as well as practically to reduce current or unseen effects on disparaged populations. Grounding environmental justice issues in scientific principles can assist in changing the subjective nature of policy creation, as highlighted by Robyn (2002):

"Policy is built on various philosophical and epistemological arguments, ultimately grounded in subjective choice, and developed using the political skills of strategy and persuasion. Based on this, the central question becomes: What philosophical and epistemological frame of reference is best suited for developing and initiating policy leading to environmental justice and power relations that are based on reciprocity rather than hierarchical domination (P. 211)."

These kinds of studies may become a tool that disparaged communities can use to organize locally, educate the general public, petition government agencies, and take legal action to protect themselves from unfair exposure (Bullard and Johnson 2000) before or during the developmental and regulatory processes. Dryzek suggests that policy analysis should address ethics and normative theory and the apparent normative basis of the status quo in the decision-making process; that is, the values and interests represented in the existing regime and policy process (Dryzek, 2000). These technologies, synthetic biology, genetically modified food, and agricultural transgenic pests, are not embedded in the current social and economic systems, nor do they have a popular response in opposition to complete embeddedness within those systems, such as genetically modified food.

This research project is meant to assist in grounding environmental justice issues under scientific exploration using several lenses of public participation in the research and development of emerging technologies in a variety of forms. Increasing public participation in the research and development of emerging technologies can assist in identifying and minimizing negative externalities that are produced with scientific and technological development and distribution, as well as increase the equitable distribution of positive externalities.

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Proprosal Addendum: Tenets of Responsible Innovation and Distributive Justice:

Public Participation in the Regulation of Transgenic Agricultural Pest:

Citrus tristeza virus

ABSTRACT

Citrus tristeza virus is a viral species of the genus *Closterovirus* that causes the most economically damaging disease to its namesake plant genus, *Citrus*. Many different publics are involved in the citrus industry. This industry is regulated by some of the agricultural agencies within the United States, including the APHIS-USDA (Animal & Plant Health Inspection Services-United States Department of Agriculture). Early inclusion of groups that have been historically marginalized has been a goal for regulatory agencies within the US for the last few decades. This type of proprosal may produce conclusions and implications that also assist in creating a platform for further research on the effects of public opinion on policy development of science. Responsible innovation benefits from including information on how the public responds to proposed regulations for implementing agricultural transgenic pests. For experts, regulators, and scholars to incorporate how future technological advances can be encompassed within a societal context, they must understand that "science that draws strength from its socially detached position is too frail to meet the pressures placed upon it by contemporary societies" (Jasonoff, 2003). The proposal stipulates a 2 level study that explores the thematic patterns and environmental justice concepts concerning agricultural transgenic pests. The first level of the study proposes to explore environmental justice thematic patterns within the 164 public comments found on https://www.regulations.gov/docket?D=APHIS-2017-0018 towards the release of the Citrus tristeza and to compare those patterns to changes within the Environmental Impact Statement (EIS) and Pest Risk Assessment (PRA). The second part of the study proposes to collect and analyze stakeholder opinions and considerations from the environmental justice community about regulating and governance transgenic agricultural pests through a workshop. Participants of this workshop work in some capacity with environmental justice issues as well as

persons who work with public participation. This includes a multi-faceted panel of stakeholders, including those from law and policy, NGO/NPOs, ecology, and other natural sciences, advocacy representatives, social experts and practitioners, and survivors of environmental injustices.

The proposed agenda for the workshop would be designed to garner research and practical ideas and discussion surrounding the topics of transgenic agricultural pests and their current development and utilization stages. The activities included in this workshop include informational presentations of current and future (developmental) transgenic agricultural pest projects and case studies, individual surveys, roundtable discussions, and presentations of those conclusions, concepts, and mind-mapping activities. The participants are given one survey at the beginning, and one after the workshop is completed, determining if there are differences in responses after various types of knowledge are provided. This research is designed to examine whether distributive justice principles are prevalent in comments made by the public regarding an emerging technology. The desired outcomes of this study will be: 1) a shared understanding of the different perspectives on transgenic agricultural pests' needs, what governance needs to look like, and challenges to achieving that governance; 2) Visual maps highlighting these ideas; and 3) Specific areas for research and engagement opportunities going forward.

Introduction

Early inclusion of groups that have been historically marginalized has been a goal for many regulatory agencies within the US for the last few decades. Wharton (1969) discussed how new agricultural technology may "constitute a cornucopia for the developing world or as opening a Pandora's Box" (pg. 465), which will bring more problems to those who utilize these new technologies. Traditional methods of inclusion of the public via notice and comment procedures for regulatory actions are often dominated by industries, trade associations, and large national environmental groups. This challenges smaller groups or individuals seeking a voice in regulatory efforts. Being that one of the known characteristics of this specific population is a lack of technical information about the technology, it may present an opportunity to attempt to understand the mechanisms that underlie the associations that exist between knowledge and attitudes about science (Allum et al. 2008, pg. 35).

Current governance strategies for transgenic agricultural pests and/or transgenic agricultural issues vectored by pests present a unique niche in emerging technologies where marginalized groups, such as those represented by environmental justice organizations, can be intentionally sought out for early input during decision-making. For example, the issue of labeling genetically engineered food and food products has been a topic of discussion for many years. The main goal of regulatory labeling requirements is to provide the consumer, i.e., the public, with choice and information concerning where and how food is derived (Gruere & Rao 2007). Food safety concerns are indirectly related to labeling as some consumers want to avoid unknown risks of foods containing genetically modified and nano-engineered ingredients (Gruere & Rao 2007) and for ethical, social, and religious reasons. Therefore, labeling policies are designed to follow safety approval standards for clearance (Gruere & Rao 2007) to give the public the means to decide their fate regarding what they ingest. This governance model may be helpful for public evaluation of transgenic pests used in food production.

Literature Review

Public opinion is formed from the public's willingness to accept prior beliefs about the technology and information barriers, which all play a crucial role in the decision-making process and, therefore, the public engagement model for policymakers. These conclusions may also assist in creating a platform for further research on the effects of public opinion on policy development. For this purpose, experts, regulators, and scholars must incorporate how future technological advances can be encompassed within a societal context. Subject-matter experts must understand that "science that draws strength from its socially detached position is too frail to meet the pressures placed upon it by contemporary societies. Instead, they imagine forms of knowledge that would gain robustness from their very embeddedness in society." (Rowe & Frewer 2000). Scholars have called for a more adaptive approach to public engagement, challenging and cautioning against the "one model fits all" mentality. Other scholars have warned that "policies involving the public must balance the desire to foster legitimacy and support for decisions with concerns to avoid priorities being driven by "the crisis of the day" including but not limited to political pressures (Moffet 1996, Rowe & Frewer 2000), hence, the case with Citrus tristeza virus.

Cozzens (2007, pg. 85) described "principles of distributive justice that underlie common rationales and goals in science and technology policy, treating four traditions in political philosophy: libertarian; utilitarian; contractarian; and communitarian." Each of these approaches is intricate in "some role in current science and technology policies: in market orientation; in the effort to maximize public benefit; in programs targeted to disadvantaged groups; and in programs that build community through involvement in research" Cozzens (2007, Pg. 85). Cozzens goes on to describe how the "variety gives national policymakers options to mix, match, and grow these elements in their national systems…making conscious decisions about the mix is important to achieving public goals in science and technology" Cozzens (2007, Pg. 85).

In Theory of Justice, Rawls (1971) proposes the principles of contract theory. Under contract theory, "a fair distribution system is one that rational individuals would freely agree to after deliberation." Rawls's works postulate that the poor and the affluent have different rules that become the starting point of each side of the negotiation toward justice, and those principles can be applied to scientific and technological policy. Rawls (1971) adds a layer to the talks of "fairness" with public policy in which each individual, each community, and each level of society has a "moral system that individuals would agree to behind a veil of ignorance, that is, they would not know what their starting position was"; therefore, they could understand each position and make policy decisions based on a viewpoint that may not be their current reality. On this basis, his theories give rise to how public decisions and participation are open to the fact that utilitarian moral principles are minute because while "total well-being increases, someone's well-being might decrease" (Rawls, 1971).

Distributive justice theory displays a significant body of empirical evidence to support the claim that "growing inequality threatens the community, within countries and globally. For instance, inequality produces worse health outcomes for everyone, not just the poor" (Galbraith, 1999). Galbraith goes on to state that a higher level of inequality causes those who are receiving the best externalities or benefits to disregard those who are getting the worst externalities. Rising inequalities cause more psychological and social distance between the haves and the have-nots and may lead to an overclass and an underclass with "hidden politics driven by money"

(Galbraith, 1999). That psychological and social distance between the haves and the have-nots can be seen in policy-making decision models like the deficit model, where only the “experts” have a say, and the public’s opinion is not considered or even deemed unnecessary and of no value. Cozzens (2007, Pg. 93) stated that.

> “the different elements serve different goals, but, like many seemingly incompatible government programs, they co-exist. That very co-existence calls attention to the options available to science and technology policymakers to mix, match, and grow these elements of their national systems. The hardest part of doing this may be knowing there is a choice”.

Those choices that Cozzens refers to underlie the principles of environmental and distributive justice.

The Regulation and Technology of Citrus tristeza virus

The government creates and modifies regulatory policies to minimize the risks to the public associated with novel technologies, including transgenic agricultural pest applications and uses. The Animal and Plant Health Inspection Service (APHIS) protects agriculture from pests and diseases within the USDA. Under the Plant Protection Act, USDA-APHIS has regulatory oversight over modern biotechnology products that could pose a risk. Accordingly, USDA-APHIS regulates organisms and products known or suspected to be plant pests or to pose a plant pest risk, including those altered or produced through genetic engineering. These are called "regulated papers" (APHIS 2017). USDA-APHIS regulates the import, handling, interstate movement, and release into the environment of regulated organisms that are biotechnology products, including organisms undergoing confined experimental use or field trials. Regulated papers are reviewed to ensure that, under the proposed conditions of use, they do not present a plant pest risk by providing appropriate handling, confinement, and disposal (APHIS 2017).

Moreover, APHIS' current regulatory structure, which entails evaluating such plants solely for plant pest risk, "is insufficient to properly identify all risks that these plants present to other plants and plant products" (APHIS 2017). Under the current structure, genetically engineered plants may entirely escape regulation. In the past, genetically engineered plants have almost always used a plant pest to vector genetic material. Still, in recent years, genetically engineered techniques have arisen that do not use plant pests as donor organisms or vectors (APHIS 2017). For genetically engineered plants, there is usually a great deal of data and experience with the non-genetically engineered organism. In most cases, these non-genetically engineered organisms are highly domesticated and cultivated widely within the United States, and there is an extensive body of scientific literature regarding their biology (Bar-Joseph 1989). However, as genetic engineering evolves and new genetic engineering techniques are developed, APHIS may "lack the technical expertise to fully evaluate certain genetically engineered organisms or classes of genetically engineered organisms. This is particularly likely when new or emerging genetic engineering techniques are applied to recipient organisms not previously subject to genetic engineering" (APHIS 2017).

Data or previous experience is available for APHIS to rely on in evaluating the properties of the resulting genetically engineered plant. Instead, to determine whether the genetically engineered plant could function as a noxious weed, APHIS would have to rely on its independent evaluation of the plant itself based on information provided by the plant's developers. An example is citrus plants affected by a disease called Citrus tristeza virus, vectored by aphids (Yokomi, Lastra, Stoetzel, Damsteegt, Lee, Garnsey, Gottwald, Rocha, Niblett, 1994).

Citrus tristeza virus is a viral species of the genus *Closterovirus* that causes the" most economically damaging disease to its namesake plant genus, *Citrus"* (Lee, 2015). The "disease has led to the death of millions of *Citrus* trees worldwide and has rendered millions of others useless for production" (Lee, 2015). Farmers in Brazil and other South American countries called it "tristeza," meaning sadness in Portuguese and Spanish, referring to the devastation produced by the disease in the 1930s. The brown citrus aphid transmits the virus most efficiently (Yokomi et al. 1994).

Citrus tristeza virus infects several species of the plant genus Citrus, including sour orange and any Citrus grafted onto sour orange rootstock, key lime and Seville orange, Hassaku orange and sweet orange, grapefruit, and mandarin (Reuther, 1978). Citrus tristeza virus is also known to infect some tropical citrus fruits such as the Chevaleir's aeglopsis of Africa, the Nigerian powder-flask fruit, and the Pamburus of India, as well as the Crinkled passionflower, which belongs to an entirely different lineage of rosid plants. Citrus tristeza virus is distributed worldwide and can be found wherever citrus trees grow (Brunt, Crabtree, Dallwitz, Gibbs & Watson, 1996; Brunt, Crabtree & Gibbs, 1990).

Citrus tristeza virus infection symptoms depend on several factors and vary from plant to plant. Some of these factors include "host, virulence of the particular virus strain, and environmental conditions" (Brunt et al. 1996). The three most common groupings of symptoms are slow decline and quick decline, stem-pitting, and seedling yellows (Koizumi 2004). The decline is generally exhibited with sweet orange, mandarin, or grapefruit when grafted on infected sour orange rootstock (Stanley 1994). This decline includes chlorotic leaves and the general death of the infected tree. Decline may be slow, lasting several months to years after the first symptoms are noticed (Stanley 1994, Koizumi 2004). "In this case, the infected tree will also show a bulge above the bud union and honeycombing on the inner face of the original sour orange rootstock bark" (Koizumi 2004). The decline may also be quick, resulting in host death just days after the first symptoms are noticed (Brunt et al. 1996, Brunt et al. 1990). Stem-pitting is another symptom of the Citrus tristeza virus that manifests in most host types under the proper conditions, especially in Citrus trees grafted onto sour orange rootstock (Reuther 1978). The host will develop pits in the trunk and stem. This results in decreased tree vigor and reduced fruit yield. This is typically caused by the more virulent strains of the Citrus tristeza virus (Koizume 2004). The third primary symptom of Citrus tristeza virus infection is seedling yellows. This tends to occur on sour oranges, Japanese summer oranges, lemons, and buntan. Symptoms include yellowing of foliage and general progressive death of the infected tree (Agrios 1997).

Citrus tristeza virus is a virus that is limited to the phloem tissues of its host. It is transmitted semi-persistently by vectors that penetrate the phloem to extract sap, mostly the aphid species that colonize the crop (Bar-Joseph et al. 1989). The brown citrus aphid is considerably more efficient at transmitting the virus than other aphids that infest citrus. In Florida, it is from six to twenty-five times as efficient as the Melon and cotton aphid, the most efficient vector found in the state before the introduction of the brown citrus aphid preceding 1995 (Yokomi et al. 1994). This efficiency is enhanced by the narrow host range of the brown citrus aphid and its tendency to produce winged forms to colonize new growth. The Melon and cotton aphid has a much more comprehensive host range, including hundreds of plant species in Florida, and the transmission of the virus is blocked when it feeds on a different host (Komazaki 1987, Denmark 1990).

Aphids are the primary vector by which the Citrus tristeza virus is transmitted. Initially, the United States only had the melon-and-cotton aphid, the green citrus aphid, and the black (or brown) citrus aphid as vectors (Stanley 1994, Brunt et al. 1996). These aphids transmit the virus much less efficiently than the oriental citrus aphid (Agrios 1997). The "oriental citrus aphid had been found in East Asia and South America and had slowly made its way up through Central America and the Caribbean Islands. By 1993, it had reached Cuba; in 1995, it was found in Florida" (Agrios 1997).

The aphids" require at least 30 to 60 minutes of feeding to acquire the virus, and remain viruliferous for at least 24 hours after" (Cambra, Gorris, Olmos, Martínez, Román, Bertolini, López, & Carbonell, 2002). Brown citrus aphid, black citrus aphid, and oriental citrus aphid are much more "efficient than the other aphids, and they can transmit Citrus tristeza virus strains, causing severe stem pitting or decline that the other aphids cannot vector" (Cambra et al., 2002). Even though "Green citrus aphid is less efficient, it tends to have higher populations and thus can still transfer the virus fairly well. Brown citrus aphid has been shown only to transmit certain strains of Citrus tristeza virus. Of the three lesser efficient aphids, the Melon and cotton aphid has a 78% transmission efficiency, while the Green citrus aphid and the Brown citrus aphid are between 0-6%" (Cambra et al. 2002). The leading cultural practice that increases the severity of the Citrus tristeza virus is when the citrus trees are grafted onto the sour orange rootstock. Using Citrus tristeza virus-infected budwood for grafting can transfer the Citrus tristeza virus from the original tree to the new one (Cambra et al. 2002).

Citrus tristeza virus is the most economically significant and damaging virus of citrus trees. It can be spread quickly and damaged by killing trees with sour orange rootstock and stem pitting standard citrus trees (Agrios 1997). It has killed more than 80 million trees worldwide, mainly in South Africa since 1910, Argentina (10 million), Brazil (6 million) since 1970, and the U.S. (3 million) since 1950. With the spreading of Brown citrus aphids, black citrus aphids, and oriental citrus aphids, the severity and impact have increased dramatically in Central America and the U.S. In Spain, there has been a progressive decline in production from over 40 million sweet orange and mandarin trees (Cambra et al. 2002)

When the Citrus tristeza virus was first discovered, quarantine was the best management strategy; now, quarantining only works for areas where a small number of trees are infected. The other approach that was adopted after the introduction of the Brown citrus aphid, the black citrus aphid, and the oriental citrus aphid that came to the U.S. was destroying any tree in which the budwood was not free of Citrus tristeza virus (Agrios 1997). This is a more drastic measure but must be done due to how fast the Brown citrus aphid, the black citrus aphid, and the oriental citrus aphid can spread the virus. If there is any Citrus tristeza virus in the area, avoid grafting trees on sour orange rootstock and instead graft on tristeza-tolerant rootstock (Agrios 1997). Since the virus has been in Asia for a long time, they have used rootstock from Japanese or Chinese bitter oranges, Sunki sweet oranges, and Taiwan tangerines for many years. Some hybrids, such as Troyer citrange, which is a hybrid between the Japanese or Chinese bitter orange and the Washington navel orange, or Swingle citrumelo, which is a cold-hardy citrus hybrid between a Duncan grapefruit and a Japanese or Chinese bitter orange, show promise as a resistant root-stock. Also, scion varieties that are tolerant to stem pitting is recommended (Brunt et al. 1996). In most cases, one plant is selected for its roots called the stock or rootstock. The other plant is selected for its stems, leaves, flowers, or fruits and is called the scion or cion (Hottes 1925). The scion contains the desired genes to be duplicated in future production by the stock/scion plant.

The management of this issue has taken many forms in the past. The "production of virus-free trees by shoot-tip grafting or heat treatment is significant." If it is "possible to keep the field permanently free of Citrus tristeza virus, planting virus-free trees is practical" (Brunt et al. 1996). In areas where it is difficult to find a virus-free field, "inoculation with a mild Citrus tristeza virus strain protects trees against infection with a severe strain of Citrus tristeza virus" (Brunt et al. 1996).

In the past, a biological solution to the Citrus tristeza virus vectorized by aphids has been to bring in a parasitoid wasp from Asia that naturally controls the Green citrus aphid. This approach was stopped because the Brown citrus aphid, the black citrus aphid, and the oriental citrus aphid arrived, and it is not a parasite of these more important aphids (Brunt et al. 1996). There is a natural parasite of aphids, a fly from the gall midge family Cecidomyiidae, that attempts to keep aphid levels down, but due to the influx in aphid population, it has not been able to keep populations down" (Stanley 1994). This is where agricultural transgenic methodology creeps into the conversation to preserve this cash crop.

A transgenic organism "is any living creature, such as a bacterium, plant, or animal, that has received a foreign gene by means of genetic engineering" (Miller, 2004). There are a variety of applications for transgenic organisms used in the American health and food industrial complexes. For example, "experts have developed transgenic silkworms that spin industrial-strength or glow-in-the-dark fibers, or make silk with human proteins" (Miller, 2001). Mosquitos have been engineered to be unable to carry one type of malaria parasite (Pew Initiative on Food and Biotechnology report, 2004). Field tests are "underway to determine the safety of using transgenic pink bollworms, designed to spread sterility to wild bollworms, to protect agricultural crops" (Miller, 2004). Due to the bulk of transgenic research still being in the developmental phase, "it is time to address the impact of transgenic applications on the environment, crop production, and animal and human health" (Hoddle, 2004). Insects are engineered to be transgenic "when one or more DNA sequences from other organisms are inserted into their

> genome. The accepted method for making transgenic insects is to splice the DNA intended for insertion into a mobile element, also known as a 'jumping gene.' A jumping gene is a segment of DNA that can be integrated at many different sites along a chromosome" (Miller, 2001).

Paratransgenesis is a technique that attempts to eliminate a pathogen from vector populations through transgenesis of a symbiont of the vector (Beard et al. 2001). The goal of this technique is to control vector-borne diseases (Bextine et al. 2003). The first step of the paratransgenesis process is to "identify proteins that prevent the vector species from transmitting the pathogen. The genes coding for these proteins are then introduced into the symbiont so that they can be expressed in the vector" (Beard et al., 2001; Bextine et al. 2003). The final step in paratransgenesis is to

> "introduce these transgenic symbionts into vector populations in the wild. The key feature of symbiotic control, which uses symbionts to control pests or disease, is identifying a symbiont that has both an intimate relationship (called mutualism) with a diseased host and access to the pest or pathogen attacking it" (Miller, 2004).

Miller describes two different types of control: biological and symbiotic. The main difference between symbiotic control and biological control is that biological control uses organisms to control pests or diseases. These organisms include parasites or predators. Symbiotic control, on the other hand, is from microbial pesticides. Microbial pesticides are used in the same way as commercial insecticides. As compared to commercial insecticides, microbial pesticides have more excellent selectivity and reduced side effects. This greater selectivity results from the ability to design the symbiotic agent to target only the pathogen causing the disease. The transgenic pest organism, in this case, acts as a symbiotic control agent. (Miller, 2004).

Recently, a genetically engineered version of the Citrus tristeza virus has been submitted to APHIS for permission to release it. The U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) announced the availability of a draft Environmental Impact Statement (dEIS) for public review and comment. This document "comprehensively evaluates the environmental impacts that may result from the potential approval of a permit application from Southern Gardens Citrus Nursery, LLC, for the environmental release throughout Florida of genetically engineered Citrus tristeza virus" (APHIS 2017). APHIS is also "making available a preliminary Pest Risk Assessment (PRA) that analyzes the plant pest risks associated with using this genetically engineered plant virus as a biological control agent" (APHIS 2017). The purpose of the proposed permit is to "use genetically engineered Citrus tristeza virus as a biological control agent to help manage citrus greening disease, also known as Huanglongbing (HLB)" (APHIS 2017).

With the citrus industry being a massive industrial complex, HLB is a debilitating disease by all accounts. Lin (1954) states that "it reduces yield, causing misshapen or small green fruit and renders the fruit bitter and unmarketable, while at the same time causing citrus trees to die. HLB is always preceded by the appearance of an insect known as the Asian citrus psyllid (ACP), which introduces a disease-causing bacterium into the plant". At the time, strategies such as tree removal and intensive insecticide applications as "soon as ACP is detected are the only available management options for HLB" (APHIS 2017). The USDA believes "these options are unlikely sustainable" (APHIS 2017).

Researchers have genetically engineered the Citrus tristeza virus to carry a gene from spinach that enables the tree to produce a protein known as defensin (APHIS 2017; Thomma et al. 2002). Defensin proteins are common in plants consumed by humans, such as spinach, wheat, potato, and sunflower (Thomma et al. 2002). The genetically engineered Citrus tristeza virus is introduced by grafting it onto a tree that needs protection (Thomma et al. 2002). This means it is not sprayed or applied to the soil but instead attached directly to the tree (APHIS 2017). The tree will produce the defensin protein after the genetically engineered Citrus tristeza virus is introduced into the tree (Thomma et al. 2002). This process shows promise both in protecting trees from contracting citrus greening disease and in treating trees that are already infected. The aphids that usually transfer the Citrus tristeza virus will be used to do so; therefore, moving it from one tree to another protects the trees from both the devastating effects of non-genetically engineered Citrus tristeza virus as well as HLB (APHIS 2017). Southern Gardens Citrus Nursery LLC, the developer of this genetically engineered Citrus tristeza virus, "has already conducted small-scale, confined applications of genetically engineered Citrus tristeza virus with promising results. It now seeks to conduct a large-scale deployment of this genetically engineered Citrus tristeza virus as a biological control agent" (APHIS 2017).

Because the biocontrol agent is a virus of citrus trees and, therefore, is a plant pest, USDA's Animal and Plant Health Inspection Service (APHIS) prepared a Pest Risk Assessment to carefully assess the risk to agriculture posed by the proposed deployment, according to the Plant Protection Act. APHIS also prepared a draft Environmental Impact Statement to 'examine any potential direct and indirect impacts to the environment that might result from approving the permit request' (APHIS 2017). This biological control agent approach for controlling citrus greening disease does not involve genetically engineering trees. Instead, the gene from spinach that enables the production of the defensin protein will be delivered to the tree's circulatory system as part of the genetically engineered Citrus tristeza virus. The genetics of the tree does not change (APHIS 2017). Citrus tristeza virus is common in citrus trees and has always been in orange juice and other citrus products (Cambra et al. 2002). The same will be true of citrus food products from trees inoculated using genetically engineered Citrus tristeza virus. The food products from these inoculated trees will contain the defensin protein that protects against citrus greening disease (Cambra et al. 2002).

Since this genetically engineered Citrus tristeza virus is intended to eliminate the pest that causes citrus greening disease, it will also undergo an approval process at the Environmental Protection Agency to ensure that its use is safe for the environment and that food from treated trees will be safe to consume. In addition, "Southern Gardens, the developer of this genetically engineered Citrus tristeza virus, has contacted the Food and Drug Administration regarding Southern Gardens' work to address citrus greening disease (APHIS 2017). The spread of genetically engineered Citrus tristeza virus to other trees that have not been inoculated is unlikely (APHIS 2017). There is not expected to be any distribution and dispersal of this genetically engineered Citrus tristeza virus beyond the inoculated trees" (APHIS 2017).

Swift (1995, 1999) and Miller (1999) conducted surveys of this literature that argued for how "distributive justice should take the beliefs of the population seriously, though not uncritically" (Lamont & Favor 2017). Walzer (1984) argues that the "distributive decisions arising through the legitimate application of particular democratic processes might even, at least in part, constitute distributive justice." The importance of this study calls on the need to create data on "people's beliefs about distributive justice, which is also useful for addressing the necessary intersection between philosophical and political processes. Such beliefs constrain institutional and policy reforms that are practically achievable in any generation, especially when the society is committed to democratic processes" (Lamont & Favor 2017).

Theories of public engagement and public opinion can be used to understand the public's role in policy creation and implementation strategies of emerging technology, including the development, release, and regulation of transgenic agricultural pests. The regulatory process involves science-based risk assessment and uses the public forum as a "sounding board to uncover potential issues the public might have with registration and use of the agricultural pest. The genetically modified pink bollworm project uncovered an attitude in some individuals and groups that we "should not be doing this," and this view was officially adopted by the California Fish and Game Commission" (APHIS 2017).

Regulatory officials must respond to objections to the application of new technologies but are limited to responding to vague fears. "Regulatory officials can measure and deal with safety issues presented by the public" (APHIS, 2017). The "economic, political, and social frameworks that each society has—its laws, institutions, policies, etc.—result in different distributions of benefits and burdens across members of the society" (Lamont & Favor 2017). These "frameworks are the result of human political processes, and they constantly change both across societies and within societies over time. The structure of these frameworks is important because the distributions of benefits and burdens resulting from them fundamentally affect people's lives" (Lamont & Favor 2017). Lamont & Favor argue "about which frameworks and/or resulting distributions are morally preferable constitute the topic of distributive justice. Principles of distributive justice are, therefore, best thought of as providing moral guidance for the political processes and structures that affect the distribution of benefits and burdens in societies, and any principles that do offer this kind of moral guidance on distribution, regardless of the terminology they employ, should be considered principles of distributive justice" (Lamont & Favor 2017).

Historically, information about an emerging technology is often lacking within the environmental justice community. This is often a reason why the environmental justice community's input concerning emerging technologies is not given by or sought by these communities early in the developmental stage (both of the technology itself, the utilization or commercialization, or the regulatory policy of the technology). Kellogg & Mathur (2003) state that "a key component of the equitable development and implementation of environmental policies is the participation of citizens and community-based organizations in the policy process. Such participation rests upon equitable access to agency-generated environmental information and effective use of that information by citizens" (pg. 573).

Methodology

The proposal stipulates a 2 level study that explores the thematic patterns and environmental justice concepts concerning agricultural transgenic pests. The first level of the study explores environmental justice thematic patterns within the 164 public comments found on https://www.regulations.gov/docket?D=APHIS-2017-0018 toward the release of the Citrus tristeza virus and compares those patterns to changes within the Environmental Impact Statement (EIS) and Pest Risk Assessment (PRA). Since the release of the information discussed above, 164 public comments have been available on the federal register since June 25, 2017. An open forum for further public deliberation was opened on April 15, 2019, and closed in June 2021. The goal of this research is to explore the public's view of the emergence and regulation of this genetically engineered plant pest vectored by a variety of aphids as well as its utilization as a biological control agent for a second disease.

Research Questions

The following research questions will be addressed in this Part 1 analysis:

- How do the environmental impact statement and pest risk assessment address the concerns of the comments made by the public in this forum?
- Do people who participate in the Notice Public Comment sections care about environmental justice concepts?
- How does the agency address the comments about environmental justice?
- How could the APHIS-USDA plan to consider legitimate claims to safety concerns with the approval or disapproval of this release, if any?

The purpose of the second part of the study is to collect and analyze stakeholder opinions and considerations from the environmental justice community about the regulation and governance of transgenic agricultural pests through a workshop. Participants of this workshop work in some capacity with environmental justice issues as well as persons who work with public participation . This includes a multi-faceted panel of stakeholders that may include those from law and policy, NGO/NPOs, ecology, and other natural sciences, advocacy representatives, social experts and practitioners, and survivors of environmental injustices. This workshop will follow Jasonoff's (2003) model of "technologies of humility" that attempt to create an environment of "participation that pays attention to framing, vulnerability, distribution, and learning" (pg. 223). The workshop attempts "to lead neither to a hardening of positions, nor to endless deconstruction, but instead to richer deliberation on the substance of decision-making" (pg. 240) regarding transgenic agricultural pests.

The agenda for the workshop has been designed to garner research and practical ideas and discussion surrounding the topics of transgenic agricultural pests and their current development and utilization stages. The activities included in this workshop include informational presentations of current and future (developmental) transgenic agricultural pest projects and case studies, individual surveys, roundtable discussions, and presentations of those conclusions, concepts, and mind-mapping activities. The participants are given one survey at the beginning of the workshop and one survey after the workshop is completed, determining if there are differences in responses after various types of knowledge are provided.

The first part of the workshop is designed to provide the participants with information about transgenic agricultural pests. This information is not meant to sway opinion in any way and will be reflective of facts as well as presentations that reflect different perspectives of value and ethical arguments. Studies have shown that the effect of knowledge on acceptance cannot be generalized wholesale from one application or method to others" (Meilby et al., 2012, pg. 155). The topics or activities within the workshop will be as follows: Transgenic Agricultural Pests Overview; Current Regulatory Landscape; Presentation of Transgenic Agricultural Pests Regulatory Case Studies; Presentation of Current, Global, and Integrative Pest Management (IPM) Activities.

The second part of the workshop will include sessions designed to capture ideas from roundtable discussions, concept mapping, and mind-mapping activities. These sessions will capture topics like group commonalities and differences between the types of transgenic agricultural pest techniques and applications, as well as the differences between the different types of environmental justice stakeholders. The other topics that will be captured within these sessions and surveys are the value and ethical concerns of the environmental justice community and the identification of the key barriers and opportunities for the ideal governance of transgenic agricultural pests. The mind and concept-mapping activities center on available environmental justice information for governance, as any risk management conversation is going to center around available information.

What the study will look for…

Distributive justice refers to the fair allocation of benefits and burdens in society among individuals with varying needs and claims based on moral norms, entitlements, efficiency, and other relevant considerations. To look for distributive justice, one must examine how resources, opportunities, or burdens are distributed within a group or society. The focus is on whether the allocation is perceived as fair based on principles like equality, equity, or need. One must also consider factors like individual contributions, needs, and access to essential goods and services. This rubric is essentially asking whether everyone is getting a "fair share" based on relevant criteria (Schaafsma, Ahn, Castro, Dendoncker, Filyushkina, González-Jiménez, Huambachano, Mukherjee, Mwampamba, Ngouhouo-Poufoun, Palomo, Pandit, Termansen, Ghazi, Jacobs, Lee, Contreras, 2023).

There are some key aspects to consider when looking for distributive justice. First is equality, meaning *do all individuals receive the same amount or level of something, regardless of their situation?* The next aspect is equity, meaning *are resources distributed proportionally to individual needs or contributions, ensuring everyone has a fair chance to reach a similar outcome?* The third tenet is a need-based distribution, meaning *resources are allocated primarily to those who require them most.* (Kaufman, 2012)

There are other supplemental but no less important considerations when assessing distributive justice. The first includes *perceived fairness*. Even if a distribution system is technically equitable, individuals may still perceive it as unfair if they feel their needs are not being adequately met (Kaufman, 2012; Schaafsma, et. al., 2023). *"…The virus is being tested to* *fight citrus greening disease, but its environmental and health impacts are unknown. I oppose the release of the genetically engineered Citrus tristeza virus into the environment for the following reasons: Once the GE virus is released, any organism (birds, insects, etc.) that comes in contact with GE virus-infected trees or their debris may be exposed. It is unknown what impact this will have on those non-target organisms because testing on these organisms has not been done. Organisms, such as aphids, etc., that come in contact with GE virus-infected trees may be able to spread this virus to other citrus groves. Any organism (birds, insects, etc.) and natural forces such as hurricanes, wind, or flood could carry debris from GE virus-infected trees to other citrus groves, and this could allow aphids, etc., to spread this GE virus to uninfected groves farther than they could normally travel. Non-GMO and organic citrus groves may come in contact with debris from GE virus-infected trees and, therefore, risk a loss of profit from their inability to sell their product as non-GMO or organic. There is potential for citrus fruits from GE virus-infected trees to accidentally make it to the market, and human safety has not been evaluated. Once this GE virus is released into the environment, it cannot be recalled. With unknown environmental impact and the inability to contain it, GMO Citrus tristeza virus release is another exercise in insanity."*

The next supplemental consideration is *social context*. Different societies may have different norms and expectations regarding what constitutes "fair" distribution (Kaufman, 2012; Schaafsma, et. al., 2023). *"Also noted in its review of the permit application, APHIS has determined that the commercial release of genetically engineered CTV does not involve genetically engineering citrus trees and that the use of the genetically engineered CTV will have no impact on the genetics of the trees or fruit. This is an excellent example of research and innovative solutions that USDA and other government agencies should support. While the permit* *is limited in scope, it is critically important to fully access the technology's efficacy and advance the technical development of this product. The permit should be supported. The food security challenge ahead is formidable, especially given the fragile environment and the innovation pipeline that must be enabled to drive sustainable growth in agriculture. Farm Bureau supports the Southern Gardens Citrus Nursery, LLC permit application and this type of innovation, which will continue to increase the global competitiveness of U.S. agriculture and potentially save an industry and a way of life for Florida citrus growers."*

The last but not least of these subplemental considerations is *power dynamics*. This consideration posits to analyze if certain groups have disproportionate influence over resource allocation. (Kaufman, 2012; Schaafsma, et. al., 2023). *"...As a graduate student in Plant Pathology, it is always exciting to hear about the application of technologies to fight plant diseases. Applying a genetically engineered citrus virus to express plant defense compounds would be perfect for helping control this devastating disease. The devastation of citrus greening was obvious. Entire orchards were wasting away, many abandoned by farmers. ... It seemed obvious that the only option for saving the citrus industry is either GE citrus or some other strategy, such as a gene drive to eliminate the vector insect. GE citrus, though promising, has constantly been attacked by non-profit "environmental" and anti-GMO groups. The rise of GMO labeling makes any GE citrus tree unappealing to farmers, and the FDA / EPA regulatory burden makes it impossible to commercialize such a tree. This leaves one option: re-purposing a pest as a biological control agent through genetic engineering. I have no experience in virology. I'm a bacteriologist by trade, but I have met many experts who have devoted their lives to ensure technologies such as this eventually make their way to farmers. It is time for the U.S. government to stand against bullying non-profit groups and make a stand for science.*

To determine whether distributive justice has taken place, individuals often turn to the behavioral expectations of their group. If rewards and costs are allocated according to the designated distributive norms of the group, distributive justice has occurred (Kaufman, 2012). Stakeholders who responded included business owners, residents of the release area, environmental groups, and experts (self-identified). The U.S. government can be considered a stakeholder but a different kind, as it is the agency that released the treatment. Out of the 164 comments, preliminary review highlighted some of the thematic patterns throughout the comments. These included but were not limited to unanticipated risks, food shortages, unknown negative externalities, animal rights, genetically modified food, public participation, and several others.

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FOOTNOTES

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