The Boundary Layer between Science and Policy in Public Decision Making

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ABSTRACT

Society relies on a fragile and often tense relationship between policy and science to make informed decisions about everything from how much of a food additive should be allowed in a breakfast cereal to where a nation should locate its radioactive waste repositories. While forecasted projections, resource allocations, and understanding of the second and third order effects of the decisions we collectively make as a society should be based on scientifically sound and validated data, evidence, and observations, often the connection between these two foundational elements is not well understood.

Policy makers often have little understanding of the scientific process, the boundaries of statistical analyses, the meaning of the data they use, or the ramifications of scientific uncertainty. Similarly, scientists often have little insight into how the data and hypotheses they generate will ultimately be used to form or modify governing principles or the allocation of public resources. In order to strengthen the vital connection between science and policy, researchers and public institutions need to explore the interconnectivity of those realms in hard science as well as their political and social science context.

(Keywords: decision making, scientific uncertainty, public policy, politics, resource allocation, evidence-based policy, the precautionary principle)

INTRODUCTION

Throughout most of human history there has been an uneasy relationship between the fundamental disciplines of the hard sciences and the sphere of public policy, politics, and governance. Public policy drives the development of our societal framework, lays out the purpose and objectives for our collective efforts, and coalesces the guidelines for how we operate in society. In order to develop sound policy based on observed conditions and relationships, politicians require unbiased, accurate, and high-quality science to support their decision-making processes. At the same time, scientists and policy makers often have very different goals, standards for information, time schedules, and professional language, resulting in significant barriers to information sharing, knowledge transfer, and even fundamental trust between the two groups (Choi, *et al*., 2005).

An additional complication to the relationship between scientists and policy makers rests in the fact that political decision makers have a level of control over a substantial amount of the support required for scientific research and technological development, thereby influencing the course of science itself. Additionally, while most politicians and policymakers will publicly state a strong desire to have sound science as the basis for their policy frameworks, they are by no means bound to use scientific data properly, or even at all. Indeed, policymakers are free to eschew or completely disregard objective data and observations when it does not support their objectives, with little or no real consequence for their political careers.

Worse still, policy makers often intentionally offer scientific findings out of context, with disregard to the validity of metadata, present data as fact beyond any reasonable statistical bounds, or even offer outright prevarications in an attempt to actively influence the political dialogue around an issue (Goodman, 2016; Maranto and Stern, 2022). These conditions are the chief source of the ever-present tensions between the scientific and political communities (Silver, 2005).

While the term “sound science” is part of the ubiquitous political dialogue at all levels of government, the term tends to have an un-fixed meaning in policy circles which shifts in relation to the intent and motivation of the speaker. The term often is used as a descriptor for science which supports the views and actions of the policy maker, rather than an accurate characterization of the rigor and standards observed in the collection of the data or development of the analysis. Policy makers often look for evidence to support their positions, thus creating a systematic bias in the way they look at data (Choi, *et al*., 2005). This, to many scientists, is the opposite of what "sound science" should be.

Alternately, the term is often used by bureaucrats to signify a scientific theory for which there are no controversial (or at least difficult to dismiss) counterpoints. The unvarnished truth of the matter is that there are rarely issues in science that are resolved to the point of absolute certainty. There are, after all, only a few hundred scientific principles which rise to the level of scientific laws. These deal primarily with mathematically provable relationships in gravitation, relativity, thermodynamics, electromagnetism, fluid dynamics, chemistry, geophysics, and the like. The number of scientific theories, however, that have been and currently are postulated to explain what we observe in nature, and that we have experimentally derived in the laboratory, number in the hundreds of thousands. These theories are all subject to scrutiny and debate.

In the wake of the Coronavirus disease pandemic (COVID-19), the mantra of "Trust the Science", has turned from a call for reason-based analysis that emphasizes the importance of relying on scientific evidence and expert consensus in decision-making into a cudgel to dismiss dissent, eliminate transparency, and blindly trust official predictions (Simons, 2021). To mitigate these risks, it's crucial to promote a nuanced understanding of "trust the science" that emphasizes critical thinking, transparency, humility, and openness to debate. Encouraging constructive critique and ensuring accountability in decision-making processes can help guard against the misuse of this phrase as a tool to repress dissent. Ultimately, fostering a culture of scientific integrity and open inquiry is essential for harnessing the full potential of scientific knowledge to address complex societal challenges.

Sound science (i.e., research that follows the scientific method, has appropriate methodologies, institutes appropriate controls, has proper statistical applications, has survived the peer review process, etc.) can go a long way towards eliminating weak theories and establishing a body of evidence to support stronger ones, but it usually doesn't provide absolute confirmation of anything (Maranto, 1998b). The concepts of uncertainty and probability functions are fundamentally vital for understanding the significance of any piece of research. These factors, however, are generally not well understood by either the general public or by non-scientist policy makers.

While the differences between scientists and policy makers are very real, each community must have an understanding of each other's strengths, weaknesses, and purposes. Building a broader understanding of the use and meaning of scientific data is a concept that should be integrated into the political and social science curricula of tertiary institutions in order to facilitate the better use of scientific research as a support for public policy decisions.

This paper presents an updated exploration of the limits, boundaries, and intersections of science and public policy, initially presented in 2019 (Maranto, 2019), with additional context in the examination of how to properly support science-based decision-making and evidence-based public policies.

What Science Can and Cannot Do

Decisions which balance the public good with the competing interests of individual and civil liberties, social order, national security, resource usage, resource conservation, economic drivers, future needs, strategic initiatives, ethics, and a host of other important factors, cannot and probably should not be based solely on a scientific valuation or quantification of the observable factors underlying the position. Scientific research and observations can only provide a piece of the puzzle when solving social problems. This is a difficult fact for many scientists to digest.

A relatively simple policy decision such as how to implement a recycling program, may involve scientific analyses such as the efficiency of the reclamation process, the toxins released in the processing waste stream, the solid waste reduction of the recycling process, and the environmental factors of siting the industrial plants associated with the recycling (Wolfington and Maranto, 2008). However, the actual policy decision may involve real world factors such as the generation of jobs in the district, tax incentives provided to the recycling operators, and activism or lobbying that involve non-science-based opposition or support for the effort, to name just a few.

In traditional science education, students are taught that science is the unbiased search for truth. The reality of it, however, is that science is better characterized as the search for facts. Facts are measurable, observable, and stand against logical argument (e.g., the melting point of camphor is 175°C). Truth, by way of comparison, is a human construct that weaves together the disparate values of belief, desire, culture, perception, socioeconomics, and history and may or may not be supported by fact (Price, 1989).

Facts, when scientifically derived, can be strongly supportive of public policy decisions. As a result, we can rely on properly structured and executed scientific research to:

- Describe the characteristics and conditions of whatever system is being observed.
- Assess the linkages and connections between different systems.
- Identify where our understanding of a system is incomplete.
- Set a standard set of conditions upon which to evaluate policy decisions .
- Set limits and thresholds for policy actions.
- Provide a neutral evaluation of alternatives to some course of action.
- Provide evidence as to the effects of implemented policies.
- Predict, to some statistical level, what may happen under different policy scenarios.

Science cannot, however, provide all perspectives that often factor into human decision processes like governmental policy. No matter how sound the research methodology, experimental controls, or statistical analysis, we cannot expect the scientific community to:

- Identify the full range of values and variables that must be considered.
- Determine which values should be prioritized and which should be minimized.
- Determine what levels of risk or uncertainty are acceptable to a particular policy decision.
- Make legal, moral, ethical, aesthetic, or cultural valuations and judgements.
- Develop quality science on accelerated timelines.
- Provide answers to complex questions with absolute certainty.
- Guarantee that scientific results will not be misused to bolster a political interest.
- Guarantee that any sector of the public will garner interest/passion in the debate of ideas.
- Be the sole determinant in a policy decision.

In an examination of the integration of forestry science with policy, the USDA noted that “the turn to science often reflects a failure of other processes (political, management, legal, regulatory, negotiation)” (Clark, *et al*., 1998).

It is important that all scientists and policy advocates learn the limits of what we can ask of scientific research. Scientists should, to the extent possible, avoid drawing their analysis into the areas of value judgements, ethical equivalencies, and prioritization of societal goals. That is the job of the policy maker who will integrate scientific facts, with economic analysis, and the values, mores, and cultural preferences of their constituent groups.

While scientists need to be careful not to be dragged into situations that can put their credentials as unbiased observers into questions, they also must understand that once released into the public domain, their observations can and will be used in ways they did not intend.

Politics is More Difficult than Physics

When asked by a Princeton conference attendee in 1946, "Dr. Einstein, why is it that while the mind of man has stretched so far as to discover the structure of the atom, we have been unable to devise the political means to keep the atom from destroying us?", the legendary Nobel scientist replied, "That is simple, my friend. It is because politics is more difficult than physics" (Clark, 1955).

There is no question that science is an integral part of the political process. National and even regional/state governments require significant scientific capacity to perform and disseminate their own scientific research; monitor and evaluate outside scientific research; and assess the impact of policy decisions on issues with complex scientific content (Homer-Dixon, *et al*., 2014).

Scientists are, from the beginning of their training, taught to be objective and as unbiased as possible in their work. If that means that a scientist spends the better part of his or her career trying to advance a theory that is ultimately disproven by their own work, then so be it. All of us who have undergone classical training as scientists understand that we have an ethical responsibility to report our findings as we record them, even when they show results contrary to our interests or personal agendas.

While the standards for sound science are well established, the current state of scientific theory has never been in stasis, unless it was artificially arrested at a given level of inquiry (as in the Roman Catholic Church's treatment of the research of Galileo Galilee).

The body of human knowledge is in constant flux. What the scientific community took as gospel yesterday, may prove to be misguided fiction tomorrow. That is why science must strive to remain an open and self-correcting process. To be of value, a theory or experimental protocol need not be agreed upon by all experts. Indeed, if we required unanimity among the opinions of all scientists, very little would ever be accomplished. What is required of scientific research, however, is that it be consistently logical in its reasoning, it be testable, and ultimately, that it be reproducible (Maranto, 1998b).

The realm of political decision making, however, is bound by a different set of guidelines and many competing interests. In the body of governance, if the outcome of a scientific study does not support the stated objectives and goals of a policy, then it is often discarded. This is not a cynical statement, but rather a realization that there may be societal values or goals that influence the ultimate decision process that are not borne out by a purely scientific examination of the data at hand.

Early in my career, I was given a small dose of reality in terms of how policy decisions were shaped by perception as much as they were by the actual underlying science. When working as a consultant for the US Army Environmental Command, I was fortunate enough to be part of a ground-breaking initiative which focused on leveraging small amounts of federal funding as a partially matching incentive program for private organizations to spend their own funds in natural resource conservation efforts near to and adjoining military training lands. These projects had the effect of conserving thousands of acres of critical habitat, reducing urbanization pressures near military installations, and protecting a number of threatened and endangered species which had concentrated on military lands because of habitat destruction outside of the installation fence-lines, all while helping to ensure that the military could continue to use its training lands in support of national defense (Maranto and Lichtenstein, 2006).

The projects were a win for the conservation groups, a win for the natural environment, and a win for national security. Nonetheless, one of our larger projects was politically attacked and even made it into the "Congressional Pig Book" of wasteful government pork-barrel projects, largely for the sin of being based in Hawaii (Citizens Against Public Waste, 2007). Obviously, anything the government funds on a beautiful Pacific island has to be wasteful. No logical statement of the underlying conservation science or the economic return on investment for those projects could persuade their detractors otherwise.

The Goal of Evidence-Based Policy

Evidence-based public policy is essential for ensuring that decision making is grounded in empirical research, sound data, and expert analysis rather than ideology or anecdotes. It helps ensure that policy interventions and political strategies are based on rigorous evaluation and research. By identifying the most effective and efficient approaches to addressing societal challenges, evidence-based policies also help allocate resources more logically, with the goal of maximizing the impact of public investments and reducing waste. Evidence-based policies also, to some degree, hold policymakers accountable for their decisions by requiring them to justify choices based on empirical evidence rather than personal preferences or political expediency.

While it is possible for bad policy to be developed based on good science, and conversely, for good policy to be developed with bad or no scientific basis at all, there has been a general consensus among governing bodies, that sound science before and after a policy decision helps to frame the problem and to assess the effectiveness of the policy itself (Haskins and Baron, 2011; Choi, *et al*., 2005). Over the last several decades, the importance of using science as a supporting platform for public policy has been recognized, yet there remains a debate over how best to achieve this goal. The framework of "evidence-based policy" has led to greater integration of science and scientists into the policy making process (Homer-Dixon, *et al*., 2014). This has also been furthered through the steady growth of centers of scientific expertise within government bodies (in the United States prime examples would include the many federal agencies with a science-based mission focus like NASA, NOAA, USDA, DOE, NIH, CDC, etc.).

Despite efforts to better encapsulate scientific data into the public policy process, full integration has not yet been broadly achieved. One factor that has limited the broad implementation of an evidence-based policy approach relates to the timeliness of available data and analysis. While public policy makers like to talk about being proactive and progressive in their approach to planning and policy development, in reality, most governmental policy is based on a reactive timeline. Often, decisions and policies are developed in response to a rapidly developing situation or under emergency conditions, and as such, cannot fully afford the long timelines required for the development, review, and verification of sound science (Clark, *et al*., 1998).

Policy makers can often be frustrated because the body of science cannot provide a quick, clear, and understandable answer to a problem as it occurs. Likewise, scientists are similarly befuddled by demands from politicians for expedient and absolute responses to problems where observations and data may not exist or where detailed answers may be years or decades away (Lawler and Collen, 2023; Choi, *et al*., 2005).

Science and policy have at their core different decision drivers. Scientists have long (often generational) attention spans, allowing answers to be probed based on successive rounds of improving observations and experimentation. The scientific process is designed to be slow, ponderous, and deliberate. Policy makers, however, do not enjoy the luxury of time. They look for concise nuggets of information that are readily available and can be pressed into service when needed. The data need not always be rigorous and often encompasses unscientific polls, anecdotes, and limited case studies (Choi, *et al*., 2005).

The Importance of Transparency in Science

Transparency in science is crucial for ensuring the credibility, reliability, and integrity of research findings and for fostering trust among policymakers, stakeholders, and the public. Transparent reporting about scientific methodologies, data, metadata, research funding sources, and results enables other researchers to replicate and verify scientific findings and understand any influences or conflicts of interests that may bias results.

Replicability is a cornerstone of scientific progress, allowing for the validation of results and the identification of errors or biases and is dependent upon transparency. Transparency also holds researchers accountable for their work by allowing scrutiny and peer review. It helps detect errors, fraud, or misconduct and promotes adherence to ethical standards and best practices in research (Maranto, 1998b).

Likewise, policymakers rely on transparent scientific evidence to make informed decisions about public health, process efficiency, environmental protection, natural hazards, resource utilization, and other policy questions. Access to reliable data and information is essential for developing effective policies that address societal challenges and meet public needs. Transparent communication builds trust and confidence in scientific institutions and expertise and when researchers and policymakers are open about their methods, assumptions, and limitations, it enhances the credibility of their findings and recommendations.

In 2023, the White House Office of Science and Technology Policy (OSTP) launched a Year of Open Science, announcing actions across the federal government to advance open, transparent, equitable, and secure research. Activities were centered around five major themes of strengthening open science policies; investing in open science infrastructure; supporting the building of open science skills; engaging communities in broader participation; and promoting incentives for open research practices (OSTP, 2024).

The principles of open-source science are to make publicly funded scientific research freely available, fully transparent, universally inclusive and accessible, and to support the scientific mandate of publication of quality and reproducible findings. It has been acknowledged by programs such as the Transform to Open Science (TOPS) that advances in technology and the development of collaborative tools and cloud computing help enable and facilitate open-source science, but to truly implement it requires a cultural shift to a more transparent and collaborative scientific process (TOPS, 2024).

As an example of the embracing of open and transparent science, in the NOAA Response to the Science Advisory Board Report on Open Data and Open Science, the Agency acknowledged that as it migrates more and more systems to the cloud, it has the "opportunity to fundamentally change the way it conducts science and manages the data and products it creates". NOAA has moved to align data collection, product development and software development into more enterprise algorithms producing consistent data products that will be shared broadly with the public (NOAA, 2023) .

Likewise, NASA is making a long-term commitment to building an inclusive open science framework to provide public dissemination and data products to the public across all of its observing systems. The NASA Office of Science states, "Open-source science is a commitment to the open sharing of software, data, and knowledge (algorithms, papers, documents, ancillary information) as early as possible in the scientific process" (NASA, 2024) .

The push towards advancing transparency has also extended to the health field where organizations like the Center for Truth in Science have been pushing for increased transparency in public health, medical, and drug study protocols (Murray, 2023).

How Scientific Uncertainty Affects Public Policy

The concept of uncertainty is one of the key tenants of science and is also one of the most misunderstood by non-scientists. Starting from the most basic formulation that very little in life happens with 100% certainty; then by extension, anything less than that has a degree of uncertainty associated with it. Science is based on inquiry and observation. Sometimes our observations are imperfect and those imperfections carry over in predictions we make based on observed patterns (SAS, 2013).

Uncertainties can generally be placed in three categories: 1) statistical, 2) model-based, and 3) fundamental. These categories correspond to the nature of observational inexactness, unreliability, and insufficient knowledge (Funtowicz and Ravetz, 1992). Both the kind and the degree of scientific uncertainty have significant implications for how policymakers can and should use scientific data.

When looking at new or evolving research, there is a heightened risk of uncertainty when compared with fundamental scientific principles or settled science that is supported by large bodies of evidence from the peer-reviewed literature. While there are often changes to our understanding of systems based on improved experimentation, instrumentation, or research design, these discoveries rarely change our understanding of scientific principles (i.e., settled science) (SAS, 2013).

Uncertainty, while often misunderstood by the general public and by non-scientific policy makers, is not completely absent from every aspect of governance. It is, for example, a common feature of all evidence-based regulatory decision-making. As an example, the basis for human, occupational and environmental health regulatory standards is to develop uncertainty- and risk-based judgments about protective thresholds (NRC, 2002; Maranto 1998a).

The public tends to construct their understanding of scientific uncertainty based on the conflicting accounts of risk presented in the media. This adds an additional layer of filter to the already complex interactions between science and public policy, in that journalists can bring their own perceptions to the coverage of controversial issues in emerging research. Uncertainty is therefore, often viewed by the public as battling interpretations between politicians, scientists, and journalists, where all three start from a common set of facts, but then construct their accounts of uncertainty related to those facts in progressive layers upon each other (Friedman, *et al*., 1999). This has led to much confusion in the general public, and sometimes outright panic, as observations and policy decisions are reported without proper context for their scientific uncertainty.

An additional issue that compounds the misunderstanding of uncertainty is the near universal trend for scientists to “hedge their bets” in publications. Indeed, it is a long running joke in the scientific community that no journal manuscript can end without the universal statement that “additional research is required”. While a clear statement of the assumptions, conditions, and uncertainties associated with any research is absolutely important, many scientists go beyond an assessment of the limitations of their data and attempt to provide proof “beyond a reasonable doubt”, which in turn requires complex caveats to their work.

Policy makers who must exercise rapid judgements, rely on a standard that is better defined as “on balance, reasonable” (Choi, *et al*., 2005). This creates a condition where policy makers are looking for a “bottom line”, while scientists seek to provide “fine print”, creating another disconnect between how science is produced and how it is consumed.

The Precautionary Principle

A common framework in public policy (especially as it relates to health, safety, and environmental protection) where there is insufficient science or elevated uncertainty is to incorporate what has become known as the “precautionary principle”. This term, derived from the German “Vorsorgeprinzip” (which translates to fore-caring principle), takes its roots from the 1970’s German clean air policies that called for forward planning to prevent the harmful effects of pollution (Boehmer-Christiansen, 1994). The concept has since been incorporated in numerous regional, national, and international policies and regulations as a standard of protection for a variety of health and environmental standards (Schettler, Barrett, and Raffensperger, 2002; Maranto 1998a).

A policy decision based on the precautionary approach incorporates the ethical aspects of proactively preventing harm. It is structured on the recognition that scientific uncertainty and gaps in the body of scientific data can lead to real and serious risks to human health and the environment (Schettler, Barrett, and Raffensperger, 2002). When boiled down to its simplest form, the precautionary principle is an extension of the ages old adage that “it is better to be safe than sorry”.

One would be very challenged to find either a scientist or a policymaker anywhere who would not agree with the statement that human health and the environment need to be protected. Where differences rapidly emerge, however, is in the level of precaution that should be incorporated into public policy to reasonably protect human health and the environment. Again, scientific uncertainty plays a role in the different views on this matter, however, there are also cost issues and ramifications from second- and third-order effects from precautionary regulations.

While from a political standpoint, the precautionary principle has a great deal of appeal, in and of itself it offers little guidance for practical public governance. Additionally, many scientists and policymakers alike have noted that precautionary decisions can themselves have their own risk and uncertainty (Sunstein, 2005).

While from a policy standpoint, it may seem prudent to ban the use of an industrial chemical until it is deemed safe (assuming for a moment that it is even possible to prove such a thing); a precautionary regulation along those lines may have dramatic and unexpected impacts for society as a whole which could include unemployment in those industries which used the compound, dependence on other compounds which may pose even higher health risks, loss of key goods to the economy, etc. Herein lays another of the conflicts that exist between scientifically derived data and the policy imperatives of proactive protection.

The Vectors of Money, Bureaucracy, and Power

While it is clear that science can have a direct impact on the course of public policy, the realm of politics can have an even greater impact on the course of science. It is not uncommon for federal agencies to create rules that direct government scientists (and to a lesser extent those funded through government grants), to seek bureaucratic approval before presenting their findings at conferences or publishing their research. Within government research agencies, travel for the purposes of attending symposia and conferences is tightly controlled. Gag-orders preventing researchers from communicating with journalists are also not uncommon in government-developed research (Homer-Dixon, *et al*., 2014).

Additionally, within bureaucracies, there is often a reluctance to examine the overall effectiveness of policies and publicly funded programs. Agencies can be resistant to such examination because there is an acknowledged understanding that many government programs, when subjected to rigorous scientific evaluation, show null results, and since no agency wants to be identified with programs that are ineffective, it becomes easier to simply not measure program effectiveness (or not accurately measure it) rather than to face potential losses in budgets and organizational power (Haskins and Baron, 2011).

While scientists are accountable to their research institutions and to the editors and peer reviewers who are involved in the publication and validation process, policy makers are accountable to a wide range of stakeholders including their constituents, the tax-paying public, political parties, other government agencies, other politicians, and the bureaucratic hierarchy of their respective agencies (Choi, *et al*., 2005). In this complex matrix of accountability, budget considerations and organizational weight play significant roles in the balance of power and the direction of public policy.

Government as a singular entity, can and does use its control over the public coffers to not only drive research in a direction that supports current public policy, but it likewise can use those funding powers to shut down or dissuade research in areas which are perceived to be counter to the political direction of a given governmental agency or regime (Dzuray and Maranto, 1999). Be that as it may, in the U.S. the diversity of funding sources available to the broad scientific community does allow for research that isn't strictly assessed to be in the policy-based public interest to still compete for non-federal funds to support their research. In the U.S., federal research funding accounts for just over 30% of the totality of available funding pool, with private industry funding approximately 60%, and all other funding sources (i.e., non-profits, universities, non-federal governments, etc.) accounting for just under 10% (NSF, 2023; AAAS, 2014; Galarraga, Werle, and Maranto, 2001).

While current government objectives and focus can, from time to time, impair the development of competing scientific inquiry, there are intervals when the push for scientific discovery matches lock-step with the stated policy directives and goals of the time. One of the best examples of this was when President Kennedy announced that America would place a man on the moon by the end of the 1960s. The geopolitical environment of the Cold War helped spur significant scientific developments and advanced much of the technology which would later drive the computer revolution (Silver, 2005).

When national interests line up with the trends in research and development, the scientific community can be the beneficiary of massive levels of resources and funding made available from the public treasury. This results in the relatively high percentages of federal research dollars focused on basic research, applied research, and development related to key governmental interests of Defense (46%), Health and Human Services (24%), and Energy (11%) (CRS, 2023). Scientists whose research aligns with government interests tend to have a larger pool of funding available for competition, and thus, development in those areas is supported to the detriment of others.

Education Challenges for the Next Generation

Introducing public policy concepts and perspectives into science courses has been a concept that has been resisted by many traditional hard science faculties, especially at the undergraduate level. This fact may stem from the reality that few tertiary science professors have been explicitly educated to teach science from such a perspective (Labov and Huddleston, 2008). In light of the ever-tighter integration of complex scientific issues in the realm of public policy, however, many now believe it to be a critical component of a balanced and multi-disciplinary science education.

It has also been observed that many non-science majors are becoming more interested in aspects of the hard sciences when they can see the relevance of the subject to other topics of interest (i.e., environmental protection, food scarcity, energy independence, crime and civil liberties, etc.) (Labov and Huddleston, 2008). This interest may in turn, be utilized to help ingrain basic scientific concepts in social science or political science students.

The National Science Foundation has acknowledged the need for integrated science and public policy education and for over 20 years has supported the Scientific Education for New Civic Engagements and Responsibilities (SENCER) program. SENCER seeks to apply current Science, Technology, Engineering, and Mathematics (STEM) content to critical local, national, and global challenges in an effort to make science more useful and civically important. SNECER has supported the development of over 50 educational models including such topics as climate change, nanotechnology, urbanization, pregnancy outcomes, and evolutionary medicine (NCSCE, 2015).

Initiatives like these will be paramount to the inclusion of cross-discipline and multi-discipline concepts in both science and social science curricula. When perused at the tertiary educational level, these programs may have the effect of focusing academic and post-academic research into a form that is more accommodating and inclusive of broader societal factors. Likewise, these efforts may help engender a higher degree of scientific literacy in the next generation of policy makers, government workers, lawyers, and social policy advocates.

CONCLUSIONS AND RECOMENDATIONS

There are several prerequisites that must be considered to successfully integrate science and public policy. These include having clear objectives and processes; having clear roles and responsibilities which include participation from the science community, policymakers, and the general public; quality control processes including peer, technical, and public review; and open communication with all stakeholders (incorporating translational scientists if necessary) (Clark, *et al*., 1998).

Educators and institutions of higher education can facilitate the movement of social policy towards a more evidence-based approach which recognizes the value of sound science along with the other social, ethical, and economic drivers that support reliable decision-making by integrating the following concepts into curriculum development and delivery:

- **Establish well-reasoned benchmarks for scientific and technological literacy at all levels of education**. Raising the understanding of the population-at-large in the areas of scientific process and current developments will support the public's understanding of developing scientific research and will provide flexibility for policy makers to move towards a more solid scientific basis for their policy decisions.

- **Provide ethical and regulatory guidance to young scientists**. Integration of both scientific ethics and regulatory standards into classical science education will engender deeper consideration for these issues among research institutions, scientific publications, and in the development of research protocols.

- **Development of a shared scientific and political language**. The situational meaning of such basic terms as uncertainty, risk, significance, etc., has led to heightened tensions and misunderstandings between scientists and policy makers. Development of common usages for these terms (or the development of alternate terms) should be integrated into both science and political science curricula, so that communications and information sharing can transpire in a more precise fashion.

- **Integrate professional organizations into the development of well-reasoned policy which properly uses science as a decision support tool**. Support the development of networking, outreach, and educational programs with key professional and academic organizations like the

American Association for the Advancement of Science, the American Chemistry Society, the American Meteorological Society, the American Geophysical Union, the American Medical Association, the International Association for Political Science Students, and the like, focused on better integration of science and policy.

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