I'll See It When I Believe It: Science Literacy and Civic Engagement

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Abstract

This paper responds to a request by the National Academy of Science to understand the relationship between science literacy, civic participation, and democratic decision making. This paper identifies general themes and specific findings that can provide relevant insight. A challenge, however, is that terms such as “science literacy” and “healthy democracy” have no standard empirical definition.

In the case of science literacy, there is a consensus among many scientists that citizens should be literate. But when it comes to what types of knowledge are necessary or sufficient for literacy, the consensus breaks down. Divisions pertain to methodological, topical, and other dimensions. As a consequence, researchers and others use the term “science literacy” to represent a wide and diverse range of empirical objects.

Similarly, what constitutes a healthy democracy depends, in part, on what an observer wants a democracy to do. Some citizens, for example, base judgments about a democracy’s health on the extent and character of income and wealth inequality. But citizens vary in their views of the optimal amount of inequality in their society. So, two individuals can look at identical data and draw very different conclusions about democratic health. Similar variations occur for other public issues like climate change.

Hence, to achieve the goals stated above, it is necessary to identify definitional analogues to “science literacy” and “healthy democracy” whose meaning is not only empirically accessible but also likely to be seen as relevant the NAS’s many constituencies. The first part of the paper focuses on this task. In the place of science literacy, I emphasize *knowledge that citizens can use to increase competence at tasks that that they value*. In the place of “healthy democracy”, I emphasize situations in which citizens in public decision contexts are *likely to demand scientific information* and desire a reconciliation of policy decisions with scientific findings.

While there is no single literature that covers the topics of this inquiry, these definitional analogues offer allow us to anticipate variations in demand for scientific knowledge across decision contexts. They also provide a basis for more effectively delivering scientific information that citizens are willing and able to use to increase quality of life for themselves and their communities.

I. INTRODUCTION. What is the demand for science literacy and what is its relationship to civic engagement?

Scientific knowledge, when applied in the right places, is a valuable social resource. Science matters today because we live in complex, interconnected societies. In these societies, quality of life depends on individuals and organizations making decisions that are consistent with reliable data and evidence. While science can produce this type of knowledge, the public value of scientific work depends what end users understand about science. When decision makers are sufficiently literate about relevant science matters, they can use what they know to improve the effectiveness and efficiency of the communities, organizations, and nations that their decisions influence. Many improvements in quality of life come from such decisions. Hence, demand for science literacy comes from individuals, private sector organizations, and public sector entities who want to achieve better outcomes for themselves and the people and environments about which they care.

At the same time, other societal factors reduce the demand for science literacy. One factor is competition. This competition comes, in part, from the fact human attention and memory are quite limited when compared with the amount of information that we can take in or recall at any particular moment. At all times, scientific information competes with other kinds of information for attention and influence.

Put another way, when individuals, businesses, governments, or non-profit organizations seek to justify real or potential actions, scientific findings are not the only reference from which they can draw. Some use personal experiences to justify their actions. Others reference the teachings of faith communities. Still others use non-scientific approaches to draw from culture and history reasons for preferring some actions over others. Science has always existed in these environments – environments in which groups and individuals recognize science as one of several plausible “ways of knowing.”

Technology also affects demand for science. Evolving communication technologies allow people from all over the world to exchange information. The breadth of the Internet’s topical coverage and the increasing ease of access through mobile devices has changed how we think about and use information. In these technologies lie new opportunities for scientific researchers and communities to communicate with audiences that are of unprecedented breadth, size, and geographical spread. Channels for increasing science literacy are more numerous than ever. These channels, however, are increasingly populated.

The same also increase the number of people and organizations who are competing peoples’ limited attention. The Internet has millions of entities seeking to use its channels to advance topics other than science. When someone wants to sell a commercial product, promote a particular version of history, advocate for an ideological approach to a social question, show videos of their cats, or develop addictive video games, the Internet is a preferred means of reaching others. Attempts to convey valuable scientific information to decision makers join this Internet traffic jam.

Today, people who seek to increase science literacy, and people who seek to use science to improve quality of life, compete with many other societal interests for attention and resources.

Some of this competition helps the spread of scientific knowledge, as occurs when competition produces more rigorous, accurate, and applicable science and when it incentivizes people to communicate scientific information effectively to public and private sector decision makers who can use it. Projects such as the Khan Academy, for example, have not only expanded access to science education for previously underserved populations, but have also been demonstrated to increase the effectiveness of more traditional educational approaches.[2]

In other cases, people who compete with science for attention seek to distract decision makers from the true content scientific discoveries. In particularly dangerous cases, self-interested individuals and organizations seek to undermine the credibility of science by aggressively marketing self-serving claims that contradict what science has discovered.[3] While these kinds of claims have long been present in the public sphere, the Internet makes them easier to distribute to broader audiences.

In this paper, I review literatures that speak to the relationship between the spread and content of scientific knowledge, civic engagement, and perceptions of science, and the extent of participation in important public decisions.

In Section II, I begin by offering a working definition of science literacy. Without such a definition, it is difficult to measure or identify relationships between what various types of people know about science and how this knowledge affects civic engagement and decision outcomes. In this section, I review debates about the kinds of information that should and should not be included in literacy assessments. A main conclusion of this section is that while competing definitions of science literacy continue, the debate's parameters clarify types of information that are more (and less) relevant to civic engagement, perceptions of science, and the scientific community's ability to help others improve quality of life. As an example of how thinking on the topic of science literacy has changed, the main example demonstrates evolving uses of the term "science literacy" in National Research Council reports on science education.

In Section III, I examine whether and how knowledge of science matters for public participation in a healthy democracy. Like "science literacy", the notion of what constitutes a "healthy democracy" is contested. I use scholarly debates about the health of democracies to draw

[2] See, .e.g, Robert Murphy, Larry Gallagher, Andrew E. Krumm, Jessica Mislevy, and Amy Hafter. 2014 "Research on the Use of Khan Academy in Schools: Research Brief." *SRI Technical Report* (funded by the Gates Foundation). https://www.sri.com/sites/default/files/publications/2014-03-07_implementation_briefing.pdf

[3] Oreskes, Naomi, and Erik M. Conway. 2008. *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. New York: Bloomsbury Press.

distinctions between cases where scientific information is – and is not -- likely to influence decision making.

In Section IV, I review empirical literatures whose evidence speaks to the kinds of educational and communicative endeavors that promote engagement as well as literatures on outcomes of science communication and attempts to improve science literacy. I give greater attention to studies where strategies are evaluated with respect to measurable outcomes. At present, there is limited overlap between previous attempts to improve science communication and previous attempts to improve civic engagement. However, studies of each topic provide outcomes from which we can learn.

By reviewing general themes and specific findings from each of these literatures and identifying their intersections and differences, we can draw insights relevant to questions such as "Does science literacy matter for public participation in a healthy democracy and can enhancing science literacy improve civic engagement." This paper's main conclusion is that when people in a decision context share common values, and when they can collectively benefit from the effective or efficient achievement of tasks that are highly valued from their shared perspective, then science is sought to help decision makers achieve desired goals. A values consensus is critical. When there is a consensus on the values associated with a problem (e.g., it is better that fewer people die from cancer, etc.), the use of science to improve effectiveness and efficiency is highly valued and relatively uncontroversial.

Demand for science literacy is mitigated when such a consensus does not exist. Consider, for example, the topic of climate change. Policy decisions in this domain go beyond science in many respects. Policy decisions reflect moral and ethical debates about how much we should change a current population's way of life in order to produce uncertain benefits for future generations. In these cases, some of those affected will resist any information that could derail their current quality of life. Given the gravity of the moral and ethical issues, others will want to base decisions on less scientific, or non-scientific, "ways of knowing." The introduction of scientific information in these cases is likely to be controversial. Controversy is likely to grow if advocates for competing sides view scientists, or one another, as exaggerating or misrepresenting findings in order to advance a particular agenda. If such attempts are sufficiently numerous, and are not effectively countered by people who can accurately convey science content, then the end result can be decreasing trust in science as a whole and a narrowing of cases where scientific expertise is sought.[4]

The emerging science of science communication, and the research community's increasing emphasis on transparency and replicability can help researchers and scientific organizations provide information that more people will want to use and that will help them participate in public decisions more effectively. The literatures reviewed in this document can enhance and

[4] Pielke, Jr., Roger A. 2007. *The Honest Broker: Making Sense of Science in Policy and Politics*. New York: Cambridge University Press.

clarify conditions under which science can motivate people to act and help them act more effectively.

II. DEFINITIONS. What are the attributes of a scientifically literate system?

To answer questions about the role and value of science literacy in perceptions of science, a healthy democracy, or civic engagement, we need a working definition of science literacy. In previous work on how to improve civic education, I have found that to develop a workable definition of literacy in these contexts, it is necessary to define and differentiate three concepts: knowledge, information, and competence. I begin our attempt to identify relevant attributes of science literacy by reviewing that argument.[5]

- Knowledge – The set of factive memories that a person or entities holds.
- Information – Records of data and observations that can be conveyed from one person to another.
- Competence – The ability to perform a task in a particular way.

A. Knowledge

Knowledge is an attribute of memory. It is the ability to remember attributes of objects and concepts and relationships among them. The knowledge that each of us has comes from our memories of past experiences and how we connect these experiences to one another.

When an individual or organization seeks to increase others' knowledge about science or other topics, they are actually seeking to cause a person to have new or different memories about these topics. Science educators, for example, are trying to affect what comes to mind when people encounter certain phenomena about the social and natural worlds. In other words, the goal of science education and science communication is to increase knowledge by aligning prospective learners' subsequent memories with findings produced by the scientific method.

Knowledge is distinguished from the concept of memory more generally because it is presumed to be *factive*. While people can remember things that are inconsistent with reality, we refer to knowledge as the justified or true attributes of memory.

A third attribute of knowledge is relevant for our purpose is that knowledge is housed in different types of memory. For example, when asked to recall a specific piece of information on

[5] See Chapter 3 of Arthur Lupia. 2016. *Uninformed: Why Citizens Know So Little About Politics and What We Can Do About It*. New York: Oxford University Press. Parts of Section II of this paper are adapted from that original text for the NAS panel's purpose.

the job, in a test, or in a conversation, people draw on declarative memory."[6] *Declarative memory* manifests as knowledge of a specific attribute of an object or knowledge of a relationship between objects. When we say that a person "knows" the answer to a question in a trivia contest, we are recognizing specific contents of his declarative memory. Yet, such abilities do not constitute the whole of a person's knowledge. *Non-declarative memory*, by contrast, includes memories of skills and procedures, as well as certain emotional and skeletal responses.[7] It often "accumulates slowly through repetition over many trials, is expressed primarily by improved performance, and cannot ordinarily be expressed in words."[8] Knowing where and how to find things is an important form of non-declarative memory. These procedural memories give us ways to access facts that are difficult to store as declarative memories.[9] When evaluating a topic to which scientific information can be relevant, people draw on declarative memories to remember a few facts about these matters and draw upon procedural memories to find additional information. Declarative and non-declarative memories together constitute the knowledge that people have when thinking about topics such as science and policy.

B. Information.

Whether we are motivated by science literacy, a desire to improve public participation in a healthy democracy, or an aspiration to improve quality of life by bringing particular scientific findings to a particular decision context, the way that we can increase relevant kinds of knowledge and competence is to provide information. Information is a means of conveying attributes of observations, data, and ideas. Information can be stored in memory and become knowledge. Unlike knowledge, however, information is not presumed to be factual. Many observations, data, and ideas that manifest as information are actually erroneous, or potentially disagreeable, representations.

It is important to note that increasing another person's knowledge is *one potential consequence* of conveying information, but increased knowledge is not an automatic or even frequent consequence of information provision. Information can be incorrect, distracting, or simply ignored. Therefore, a lingering challenge for people who wish to increase science literacy or affect public participation in important public decisions is to determine *what kinds of*

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[6] For a comprehensive and accessible review of basic facts about this type of memory, see National Research Council. 1994. *Learning, Remembering, Believing: Enhancing Human Performance*. Washington DC: National Academies Press, Chapter 3.

[7] Squire, Larry R., and John T. Wixted. 2015. "Remembering." *Daedalus: Journal of the American Academy of Arts and Sciences* 144: 53–66.

[8] Gerard Emilien, Cecile Durlach, Elena Antoniadis, Martial Van der Linden, Jean-Marie Maloteaux. 2004. *Memory: Neuropsychological, Imaging, and Psychopharmacological Perpsectives*. New York: Psychology Press, page 2.

[9] Other scholars use different terms to distinguish between kinds of memory. For example, Eric R. Kandel, James H. Schwartz and Thomas M. Jessell (1995: 656) refer to declarative memory as "explicit" and non-declarative memory as "implicit."

information can offer real value to the intended recipients. This is where the relationship between information and competence becomes relevant.

C. Competence

Competence is with respect to a task. Many researchers and science-focused organizations are motivated by the belief that increasing certain kinds of scientific literacy adds value to the societies in which they live. While educators may say that they want to "inform audiences" or "increase their knowledge", most researchers and science institutions are not motivated to change others' thinking about random or undefined topics. They typically want audiences to apply certain kinds of knowledge to certain kinds of tasks.

A common ambition for people who want to increase science literacy or related concepts is to help prospective learners to align their beliefs or behaviors with a certain set of scientific findings and related information that the researchers or educators regard as being "better" for prospective learners or a community to which they belong. In other words, the science providers often assume that bringing more science to these decision making environments will produce better decisions and better quality of life. In Section III, I will analyze this type of assumption in greater detail. For now, however, it is sufficient to recognize that a lot of the interest in topics like science education, science communication, and scientific literacy are motivated by the belief that these activities improve decisions.

D. The Most Valuable Definition of Literacy Depends on Decision Makers' Tasks

With these three definitions in hand, we can now evaluate differences in opinion about the types of knowledge that constitute science literacy and the importance of these debates to different types of competence. To characterize broader debates about what science literacy is and is not, it may be instructive to compare two highly-influential documents in which that National Research Council played an important role. The first document in the *National Science Education Standards (NSES).* Later, I will discuss the role of science literacy in the NSES's replacement, the *Next Generation Science Standards (NGSS)*.

The NSES, published by the National Academies Press in 1996, was the product of a long, rigorous, and wide ranging effort to ensure that "all students should achieve scientific literacy."[10] After an introductory chapter, the second chapter develops a definition of science literacy in great detail. This definition, from page 22, serves as the focal reference for the document's subsequent characterizations of, and advice for, the status and public value of science education.

> **SCIENTIFIC LITERACY.** Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and

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[10] National Research Council. 1996. *National Science Education Standards*. Washington, DC: National Academy Press, page ix.

> cultural affairs, and economic productivity. It also includes specific types of abilities. In the *National Science Education Standards*, the content standards define scientific literacy.
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> Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.
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> Individuals will display their scientific literacy in different ways, such as appropriately using technical terms, or applying scientific concepts and processes. And individuals often will have differences in literacy in different domains, such as more understanding of life-science concepts and words, and less understanding of physical-science concepts and words.
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> Scientific literacy has different degrees and forms; it expands and deepens over a lifetime, not just during the years in school. But the attitudes and values established toward science in the early years will shape a person's development of scientific literacy as an adult.

The NRC further relates this definition to the knowledge that greater literacy can produce (page 23).

> **KNOWLEDGE AND UNDERSTANDING.** Implementing the *National Science Education Standards* implies the acquisition of scientific knowledge and the development of understanding. Scientific knowledge refers to facts, concepts, principles, laws, theories, and models and can be acquired in many ways. Understanding science requires that an individual integrate a complex structure of many types of knowledge, including the ideas of science, relationships between ideas, reasons for these relationships, ways to use the ideas to explain and predict other natural phenomena, and ways to apply them to many events. Understanding encompasses the ability to use knowledge, and it entails the ability to distinguish between what is and what is not a scientific idea. Developing understanding presupposes that students are actively engaged with the ideas of science and have many experiences with the natural world.

In these definitions, we see references to the concepts defined above. The definition highlights the role of knowledge – in the context of knowing how to ask, find, and determine answers and knowledge of how to describe, explain and predict natural phenomena. Competences are also focal. Named competences include being able to read and understand science articles, being able to evaluate the quality of scientific information and state opinions that are scientifically informed, the ability to apply scientific knowledge to personal decisions, participation in civic and cultural affairs, and increasing economic productivity. This definition of science literacy focuses not on science knowledge for its own sake but for the sake of better decisions.

With this definition in mind, how might we identify the types of information and knowledge that can actually lead to better decisions? This question is particularly important given the quantity of scientific information produced. Since people have limited attention capacity, limited time, and limited resources for allocating to learning about science, what types of scientific information would be most valuable for individuals and broader populations to know?

A challenge for people who seek to answer these questions, is that the domains of science information and science knowledge are effectively infinite. That is, the space of all of the things that can be known about science (i.e., about its methods, findings, implications, and all possible relationships between such things), can be represented as an infinite-dimensional construct. While people can say very valuable things about science by emphasizing certain facts or dimensions, to describe or to know it all is beyond any person's comprehension.

Consider, for example, this description of the problem from Druckman and Lupia (2016)

> For scientists who seek to convey insights gleaned from studies of complex phenomena, the reality of limited attentive capacity forces them to make choices about how to convey what they know. Scientists often struggle to make these choices effectively. Their struggle arises from the fact that many scientific phenomena have many describable attributes. Since prospective learners cannot pay attention to all extant facts about complex phenomena, science communicators must make choices about what parts of their subject to emphasize.
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> This is not the only challenge facing science communicators. The scientific process is itself a complex phenomenon. Consider, for example, how a researcher examines climate change. When studying climate change, a researcher chooses which attributes of climate will be the focus of the research. With this focus in mind, a researcher chooses where, when, and how to gather evidence. A researcher also chooses what metrics to use to characterize observations. For example, when measuring ocean temperatures, a researcher can offer a continuous metric or a discrete metric. The metric can characterize very small parts of an ocean or very large parts. With measures in hand, a researcher then chooses how to analyze the observations. In many cases, researchers choose a particular statistical model – a choice that includes not only what potential explanatory variables to include or exclude but also whether to use the log or square root of a particular value. Attempts to understand the full meaning of a scientific finding can depend on knowledge of how the finding was produced.

> Because scientific phenomena and methods can be complex, science communicators are forced to choose the information about the studied phenomena and the research process to convey to prospective learners. Science communicators must decide what aspects of the topic and research design to describe first, and which aspects to convey later. They must decide which aspects to include in footnotes or technical appendices and which to exclude. Science communicators who make these choices are involved in acts of *compression.* They are seeking a means of converting high-dimensional research phenomena and multi-faceted research processes into language that is accessible and meaningful to their target audiences.[11]

Because the domain of scientific knowledge is infinite, and because social tasks differ in the kinds of scientific information that are necessary, sufficient or even relevant to highly consequential decisions, *there will never be a universal consensus on which science facts or attributes of science are most important*. Even if a large group of experts were to agree on a set of facts or practices that are critical for others to know, differences in the imperatives of diversely situated populations of prospective learners would provide the experts with motives to disagree about which of the relative importance of elements of the set of chosen facts. Biologists have different ideas about these matters than do physicists and chemists. Organic and inorganic chemists also disagree. There will be disagreements across the natural and social sciences. There will be differences across people whose interests are more basic and those who are more applied.

These challenges prove problematic for the 1996 definition of "science literacy" described above. The definition includes the phrase "A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it." At one level, this is clearly sound advice. The truth value and broader implications of a scientific claim often depends on the context in which the claim was produced, analyzed and interpreted.[12] At another level, however, this request reveals the difficulties inherent in producing universal agreement on what types of knowledge are critical to science literacy.

In every active science discipline, there are often deep debates about methodological matters. These debates occur not necessarily because one way of examining a phenomenon is right and another is wrong, though this sometimes occurs, but often because researchers are seeking to use competing low dimensional conceptual frameworks and associated instrumentation to characterize much higher dimensional phenomena. Many methodological wars reflect differences in which dimensions of a phenomenon's many potentially observable dimensions (or combinations of dimensions) are most important. Many scientific inquiries require decisions

[11] James N. Druckman and Arthur Lupia. 2016. "Using Frames to Make Science Communication More Effective." Forthcoming in Dietram Schuefele, Dan Kahan, and Kathleen Hall Jamieson. 2016. *The Oxford Handbook of the Science of Science Communication*. New York: Oxford University Press.

[12] We discuss implications of these facts for interpreting claims in political science in Arthur Lupia and Colin Elman. 2014. "Openness in Political Science: Data Access and Research Transparency." *PS: Political Science and Politics* 47: 19-42.

about what level of analysis to choose, what aspects of a phenomenon receive the greatest attention, and what kinds of errors are acceptable.

While there is an emerging consensus on the importance of reproducibility when making a scientific claim[13], even here there are important debates about what reproducibility means across different research traditions.[14] Moreover, even if science more fully converges on a principle such as reproducibility, that convergence will not settle questions about whether a particular set of basic findings from, say, quantum physics is more important to science literacy than a set of equivalently basic findings from microeconomics. Hence, *any universal claims about what constitutes "science literacy" will necessarily contain a subjective component – perhaps a significant one*. Thus, unless one group of science arbiters obtains dictatorial power over definitions, there will never be a universally agreed upon definition of science literacy.

At the same time, the fact that some subjectivity must be present in sufficiently broad or universal claims about science literacy does not imply convergence to relativism. It means that if we want to advance and defend the proposition that a certain set of scientific facts or practices are important for others to know (i.e., are critical elements of science literacy), the defense must be based on theory and evidence about how the knowledge will be used.

In other words, any claim about the public value of knowing certain types of science information to certain audiences or about the public value of increasing a particular flavor of science literacy must be defined with respect to the social tasks for which improved competence is sought. This change in perspective is not simply reflected in evolving research about how people use different types of information, it is also manifest in differences between the *National Science Education Standards* and the *Next Generation Science Standards*, which many people view as its replacement. When compared to the NSES, the NGSS relies far less on a universal notion of "science literacy" than did its predecessor.[15] In the new set of standards, the emphasis is on a framework that includes discipline-specific core ideas and the usefulness of science in performing a range of well-defined tasks.

This shift in emphasis can provide an analog for this committee's efforts to think constructively about how to distribute and convey science information in ways that have the greatest

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[13] See, e.g., John P.A. Ioannidis. 2005. "Why Most Published Research Findings are False." *PLOS: Medicine* 2: 696-701 and Brian A. Nosek, Jeffrey R. Spies and Matt Motyl. 2012. "Scientific Utopia II: Restructuring Incentives and Practices to Promote Truth over Publishability." *Perspectives on Psychological Science* 7: 615-631.

[14] Political science is one of many disciplines having a very loud, and increasingly productive, dialogue about such matters. See, for example, Lupia and Elman (2014), Tim Buthe and Alan M Jacobs (eds.). 2015. "Symposium: Transparency in Qualitative and Multi-Method Research," *Qualitative and Multi-Method Research Newsletter* 13: 2-64, and Matt Golder and Sona N. Golder (eds). 2016. "Symposium: Data Access and Research Transparency (DA-RT)." Comparative Politics Newsletter 26: 1-64.

[15] National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington DC: The National Academies Press.

relevance for civic engagement and public participation in a healthy democracy. In particular, some individuals, organizations, and societies place high value on performing certain types of tasks effectively and efficiently. These desires produce a demand for certain types of competence.

E. Summary

Having reviewed definitions of knowledge, information, competence, and science literacy, we see the basis for continuing disagreements about what it means to be scientifically literate. At the same time, we know that there are circumstances where providing scientific knowledge can influence public perceptions and decisions.

Increasing competence requires increasing certain types of knowledge. The most valuable types of knowledge are those that are necessary or sufficient to increase high-value competences. Hence, the desires described above produce a demand for certain types of knowledge. *The most valuable types of knowledge are those that are necessary or sufficient to produce desired competence levels on high value tasks*.[16] This is my working definition of what it means to be science literate.

The implication for the questions raised by the panel is that the demand for science-based knowledge depends on the types of tasks for which the demanding entity desires higher competence and on the types of information that can produce that competence. If we can articulate the reasons why we think science literacy provides value to society (e.g., increasing civic engagement and improving public participation in making critical social decisions), we can then work to identify strategies and pedagogies that produce these outcomes.

That said, scientific information co-exists with other ways of knowing. This is particularly true in public decision making contexts where moral and ethical concerns are present. Policy debates about issues like climate change and abortion can be informed by science, but are not the exclusive domain of science. These decisions also involve choices about tradeoffs between different types of people and across generations. In modern societies, these are the types of problems that gravitate to political and policy domains. In the next section, I describe the role that science plays in these contexts.

III. ANALYSIS: Does knowledge of scientific findings matter for public participation in a healthy democracy?

In the previous section, I used the concepts of knowledge, information, and competence to clarify how and why the concept of science literacy is difficult to define in a universal sense. Differences in methods, preferences for various levels of analysis, and diverse areas of intended

[16] See, e.g., Arthur Lupia. 2013. Communicating Science in Politicized Environments." *Proceedings of the National Academy of Science* 110: 14048-14054.

application can produce divergence in claims about the relative value of different types of scientific information. Yet, if the goal is to improve the quality of civic engagement on important social matters, then a universally-accepted definition of science literacy is not necessary. Instead, the question becomes when and how conveying scientific information can improve quality of life. In other words, when will individuals, private sector decision makers, and public sector participants be willing and able to base their decision calculus on relevant scientific information?

In response to the panel's queries, I will focus this question to a particular domain: How do attempts to increase certain types of scientific knowledge relate to the stated goal of public participation in a healthy democracy? To make progress on this front, we will need a working definition of what constitutes a healthy democracy. Like "science literacy" developing such a definition is more challenging than it may first appear.

A. Democracy

Readers from outside of political science may be surprised to know that there are important debates about what a democracy is, what types of governments qualify as a democracy, and what types of governments are more (or less) democratic than others.[17] Some level of public involvement, including the right of citizens to vote, is the core element of any definition. But nations vary in who gets to vote, what kinds of candidates and issues are voted upon, how often citizens can vote, and the extent to which their decisions can actually affect policy. Political systems differ across all of these dimensions. So claims about which countries are (and are not) democracies, or which countries are more (or less) democratic than others, depend on subjective assessments of which participatory and outcome dimensions are more important than others.

There is, for example, debate over whether China is a democracy. Contrary to a popular view in the United States, China does allow citizens to vote. Many Chinese citizens vote in "local people's congresses." Candidates can be nominated by the Communist Party of China, or other organizations or groups of individuals. Voting is by secret ballot.[18] These local people's congresses can influence regional or even national decisions in some cases. While it is true that most Chinese citizens have very limited ability to affect governmental decisions, if the only criterion for being a democracy is that people can cast votes that have some degree of influence over legal legislative authority, China would qualify.

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[17] Michael Coppedge and John Gerring, with David Altman, Michael Bernhard, Steven Fish, Allen Hicken, Matthew Kroenig, Staffan I. Lindberg, Kelly McMann, Pamela Paxton, Holli A. Semetko, Svend-Erik Skaaning, Jeffrey Staton, and Jan Teorell. 2011. "Conceptualizing and Measuring Democracy: A New Approach." *Perspectives on Politics* 9: 247-267.

[18] See, e.g., Chapter 7 of Hiroki Takeuchi. 2014. *Tax Reform in Rural China: Revenue, Resistance, and Authoritarian Rule*. New York: Cambridge University Press.

At the same time, some question the democratic *bona fides* of the United States. Beyond infamous historical restrictions on the right to vote, there remains today some significant barriers to the ballot box. Registering to vote is more difficult in some parts of the United States than it is in many other parts of the world. Moreover, in some 2016 presidential primary elections, states like Arizona drastically reduced the number of polling places. This decision forced citizens in some parts of the state to wait for four or more hours just to cast a ballot. These types of outcomes would cause considerable outrage in many other countries that are widely considered to be democratic.

Getting on a ballot to run for public office in the United States can also be difficult. Moreover, and, as has become apparent in the recent presidential primaries, both of the major parties' nomination processes include decidedly undemocratic elements. The Democratic Party, for example, gives unelected superdelegates significant ability to determine their presidential nominee. In 2008, it was the changing votes of superdelegates, and not a particular primary election, that clinched the Democratic nomination for Barack Obama. The Republican Party does not use superdelegates but features a byzantine collection of procedures for naming delegates to their convention. In 2016, the GOP faced many complaints about disconnects between primary election results and the actual loyalties of those individuals sent to attend the nominating convention. Moreover, the United States is one of the few widely-recognized democracies that has never allowed its citizens to vote directly on any question. Most widely-recognized democracies, including most US states, have allowed their citizens to vote directly on important questions such as whether or not to adopt or change a constitution. The United States has never done this. It has not even held an national advisory referendum -- which makes it rare when compared to our democratic peers.

Like "science literacy," there is no universally accepted definition of what is and is not a democracy. However, that need not stop us from pursuing a working definition that will help us better understand how conveying scientific information can influence perceptions of science, affect public decision making, and improve quality of life. For the purpose of this paper, I follow a standard and widely-used college textbook in American Government and define a democracy as "a system of rule that permits citizens to play a significant part in the governmental process, usually through the selection of key public officials."[19]

B. Healthy

Now to the question of what constitutes a *healthy* democracy. This too is a challenge. Many people contend that the definition of a healthy democracy is obvious: a healthy democracy produces policy outcomes *that they support*. An unhealthy democracy is one that fails to produce these outcomes. These competing ideas are problematic for our purpose. People who care about economic inequality will measure democratic health with respect to income

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[19] Theodore J. Lowi, Benjamin Ginsburg, and Kenneth A. Shepsle. 2008. *American Government: Power and Purpose*. New York: W.W. Norton and Company.

distribution metrics.[20] Those who prefer growth and care less about inequality will prefer other metrics. The underlying problem is that what different people want democracies to deliver and what governments can actually do are impossible to reconcile. Government is about managing these tradeoffs – making them go away is rarely an option.

Others speak of the health of democracies in terms of numbers of laws passed. Such metrics are behind often-heard complaints about gridlock in the United States Congress.[21] The claim that gridlock is a sign of governmental dysfunction is made against a reference point where the claimant desires Congressional action and can imagine it occurring. In other words, there are many, if not most, social issues on which Congress is silent and about which there are no gridlock campaigns (e.g., Should we paint the exterior of the Keck building red?).

Moreover, when we look at the actual functioning of Congress we see a similar story across time. In each session of Congress, many bills are introduced.[22] Very few of these bills become law. While the number of laws passed varies from Congress to Congress, all Congresses pass a substantial number of laws. The most recent completed Congress (the 112th Congress), labelled by many as the least productive Congress on record, enacted 284 laws.[23] Moreover, to compare Congresses by numbers of laws passed is to ignore variations in the content and power of what they enact. A single comprehensive budget bill can have far more influence on quality of life than hundreds of smaller bills combined.

Another way to look at gridlock is as a circumstance where there is insufficient consensus to promulgate new law. For cases where observers want simple majorities to rule, Congressional gridlock can be very frustrating. But the US political system includes many safeguards to protect the authority of states and of particular minority groups. These safeguards are not perfect, in part because – and as we will see below -- there is no such thing as a perfect safeguard in politics. But safeguards that sometimes produce gridlock sometimes also prevent certain types of small minorities from getting steamrolled in the legislative process. Some groups would be loath to give up those protections in order to reduce "gridlock." In political systems, minority protection and gridlock are two sides of the same coin. Hence, gridlock need not be a sign of an unhealthy democracy.

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[20] See, e.g., Thomas Piketty. 2014. *Capital in the Twenty-First Century*. Cambridge: Harvard University Press and Jacob S. Hacker and Paul Pierson. 2016. *American Amnesia: How the War on Government Led Us to Forget What Made America Prosper*. New York" Simon and Schuster.

[21] See, e.g., Thomas E. Mann and Norman J. Ornstein. 2012. *It's Even Worse Than It Looks: How the American Constitutional System Collided with the New Politics of Extremism*. New York: Basic Books.

[22]Norman J. Ornstein, Thomas E. Mann, Michael J. Malbin, Andrew Rugg, and Raffaela Wakeman. 2014. Washington DC: American Enterprise Institute, Campaign Finance Institute, and the Brookings Institution.

[23] https://www.govtrack.us/congress/bills/statistics

With such dynamics in mind, contemporary observers debate whether things like the health of a democracy should be measured in terms of national wealth or economic growth, while others emphasize numbers living in poverty, perceived happiness, or life spans. From the panel's description, however, I see an interest in evaluating qualities of the decisions that people make when there is the possibility of voting and when there is some degree of governmental accountability to electoral outcomes. I see an interest in when and how the use of scientific information in such decisions corresponds to increases in quality of life.

If we focus on decision quality as a measure of democratic health, the contested nature of many decision contexts makes finding a universally acceptable metric difficult. Consider, for example, the following conclusion from a longer research program on what people do and do not know about a range of policy debates:

> The stuff of politics is contestable. There is no single right way to vote, no single right position on issues, no single right set of beliefs. From the standpoint of studying citizen performance, this observation is bad news. It means that scholars cannot evaluate the quality of decisions in a straightforward fashion. Assessing performance would be simple if liberal or conservative decisions were always the right decisions or if a select group of individuals who were known to "get it right" always agreed. For scholars who study such things, unfortunately, neither is the case."[24]

In many policy decision contexts, there are no universal criteria that will be accepted as "best" by everyone. There are no silver bullets. Yet we also know that increase in scientific knowledge can help decision makers achieve important goals. Hence, the question becomes, in what decision contexts will participants want and use scientific information. The following subsection addresses this question directly.

C. Value Diversity and Demand for Science Knowledge[25]

Politics is the means by which societies attempt to manage conflicts that are not otherwise easily resolved. Issues that people typically perceive as "politicized" are ones over which salient social disagreements persist.[26] When issues cease to have this quality, they tend not to be viewed as political. Consider, for example, the fact that child labor was once a contested

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[24] James H. Kuklinski and Paul J. Quirk. 2001."Conceptual Foundations of Civic Competence" Political Behavior 23: 585-311.

[25] For an extended examination of the relationship between values diversity and the perceived value of different types of information in decision contexts, see Chapter 10 of Arthur Lupia. 2016. *Uninformed: Why Citizens Know So Little About Politics and What We Can Do About It*. New York: Oxford University Press. Parts of subsections IIIc and IIId are adapted from that original text for the panel's purpose.

[26] Arthur Lupia. 2000. "Evaluating Political Science Research: Information for Buyers and Sellers." *PS: Political Science and Politics* 33: 7–13.

political issue in American politics.[27] It was political because people were willing to voice different views about the propriety of young children working long hours in factories. Today, few if any Americans are willing to endorse American children as factory workers. Even though factories are much safer today than they were at the beginning of the Industrial Revolution, today the issue is characterized by a moral consensus against child factory labor. From a physical standpoint, nothing changed. But the emergence of a value consensus means that few, if any Americans, consider that issue to be political.

Hence, value diversity is a defining characteristic of the policy debates and political battles of any particular time and place. Value diversity also affects answers to questions like "What information is most valuable to convey?" and "*Who* needs to know *what*?" Since value diversity has both of these attributes, it also affects when decision makers will be receptive to science and when they will reject it. As a result, it also affects the correspondence between what some people would call science literacy and what some people would call a healthy democracy. To see the implications of these relationships for the panel's questions, it will be instructive to review how values affect perceptions and decisions.

I define values as do Shalom Schwartz and Wolfgang Bilsky (1987: 551). By values, they mean "(a) concepts or beliefs, (b) about desirable end states or behaviors, (c) that transcend specific situations, (d) guide selection or evaluation of behavior and events, and (e) are ordered by relative importance." By value diversity, I refer to the different values that people have. Value diversity affects claims about what is worth knowing and, hence, whether or not decision makers will seek and use scientific information in their decision making endeavors.

Values affect the types of information prospective learners are willing to pay attention to and regard as credible. Hence, the desire for greater science knowledge will depend on the extent of value diversity present in a decision context. I present the range of possible circumstances as four mutually exclusive and collectively exhaustive cases. The four cases differ in whether or not the decision makers share relevant values and whether or not they perceive greater knowledge of relevant science as helping them achieve shared aspirations. After offering an initial description of features that affect both public participation in decision making as well as interest in learning more about science, I will describe the underlying dynamics in greater detail.

1. Decision contexts in which people share relevant values and in which scientific knowledge is a perceived means to achieve shared aspirations. By providing task-relevant information effectively, science educators and communicators can help groups achieve highly valued competences. If there are no or few incentives for free riding, decision makers will be highly motivated to use science in decision making.

[27] Kaushik Basu. 1999. "Child Labor: Cause, Consequence, and Cure, with Remarks on International Labor Standards. *Journal of Economic Literature* 37: 1083–1119.

2. Decision contexts in which people with diverse values who nevertheless perceive that they can benefit from certain types of collective action. If science knowledge is to play a role in affecting this type of decision context, it must come in the form of information that is relevant to their shared problem while also transcending individual differences. Science communicators will need to be more skilled at recognizing values commonalities and differences than in groups of type 1. Otherwise, controversies about the value of science will result.

3. Decision contexts in which people with diverse values initially perceive that they cannot benefit from certain types of collective action. If science is to play a role in these situations, science and other "ways of knowing" must persuade decision makers that they have previously unperceived common interests. If that happens, the situation takes on characteristics of type 2.

4. Decision contexts in which people share all relevant values and in which scientific knowledge is a perceived threat to shared aspirations. In this case, absent a shared experience that reveals a direct and severe negative consequence effect of continuing to avoid scientific information, public participation in decisions and civic engagement will involve active attempts to deny science.[28]

When people in a decision context have a values consensus, they often view their motives as moral rather than political, they sometimes interpret their own values-based standards as universal. As Skitka (2010: 269) describes, these groups see their shared principles as "absolutes, or universal standards of truth that others should also share" and perceive their values-based views as "objective—as if they were readily observable, objective properties of situations, or as facts about the world." [29] In these cases, there can be great motivation to pursue the group's objectives (free rider problems being the biggest hurdle) and little internal motivation to compromise with others.[30] At the extreme every potential point of contact with outsiders represents a zero-sum or negative-sum engagement.[31]

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[28] See, e.g., Eric C. Nisbet, Kathryn E. Cooper, and R. Kelly Garrett. 2015 "The Partisan Brain: How Dissonant Science Messages Lead Conservatives and Liberals to (Dis)trust Science." *The Annals of the American Academy of Political and Social Science* 658: 36-66. For a review of relevant theory about when and how false beliefs can persist among highly strategic decision makers, see Arthur Lupia, Adam Seth Levine, and Natasha Zharinova. 2010. "When Should Political Scientists Use the Self-Confirming Equilibrium Concept? Benefits, Costs, and an Application to Jury Theorems." *Political Analysis* 18: 103-123.

29 Linda J. Skitka. 2010. "The Psychology of Moral Conviction." *Social and Personality Psychology Compass* 4: 267–281.

[30] See, e.g., Timothy J. Ryan 2014. "No Compromise: The Politics of Moral Conviction." Doctoral dissertation, University of Michigan.

31 See, e.g., the theoretical conception of this relationship and its implications for group decision-making in Milgrom, Paul, and John Roberts. 1986. "Relying on the Information of Interested Parties." *RAND Journal of Economics* 17: 18–32.

If such groups see scientific information as helping them to advance their shared goals, they will embrace science. They will see science as essential to progress and are likely to question the intelligence or motives of anyone who makes contrary arguments. One can expect great enthusiasm for a growing role for scientific knowledge in public decision making. The same consequences are likely, but in reverse, if decision makers with a values consensus see the information as threatening their values and as not necessary for them to achieve their aspirations. This situation is fertile ground for rejecting science.[32]

When value diversity leads people to prefer sufficiently different outcomes, it becomes harder for decision makers to draw a conclusion about the value of science without inserting a subjective claim about how to weigh implications of increasing science knowledge for different types of people.[33] For example, when an action makes one subset of a group better off at the expense of another, getting others to accept the action as legitimate requires an explanation of why this tradeoff is preferable to other tradeoffs that could be made.[34] One argument of this kind is that the "payers" should see from their own values perspective that the beneficiaries' benefit is very large relative to their personal costs and is therefore worth pursuing. Another argument is that the proposed tradeoff can or will be bundled with other tradeoffs in ways that make the payers better off when they view all of the tradeoffs in the aggregate.

Consider, for example, a situation in which achieving a policy objective requires two individuals to participate. Suppose that the two have an adversarial relationship on one issue, that they can both benefit from acting collectively on a second issue, and that the desired outcome on the second issue requires compromise or collaboration on the first issue. In such cases, the "sweet spot" for collaborative decision making is to identify information that is (a) necessary or sufficient to increase competence on the second issue, and that (b) reflects both individuals' common interests on the second issue to such an extent that any disagreement on the first issue is outweighed by the benefit of their collaboration on the second.

D. Summary

Understanding how values affect receptiveness to scientific information can empower individuals who, and organizations that, care about the quality of public decision making. It can

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32 See, e.g., Charles S. Taber, and Milton Lodge. 2006. "Motivated Skepticism in the Evaluation of Political Beliefs." American Journal of Political Science 50: 755–769, Brendan Nyhan and Jason Reifler. 2010. "When Corrections Fail: The Persistence of Political Misperceptions." *Political Behavior* 32: 303–330 and Brendan Nyhan and Jason Riefler. 2015. "Does Correcting Myths about the Flu Vaccine Work? An Experimental Evaluation of the Effects of Corrective Information." *Vaccine* 33: 459–464.

33 My thinking in this passage is influenced by work in social choice theory, particularly Amartya Sen. 1998. "The Possibility of Social Choice. Nobel Lecture, December 8, 1998." *American Economic Revie*w 89: 349-378.

34 John W. Patty and Elizabeth Maggie Penn. 2014. *Social Choice and Legitimacy: The Possibilities of Impossibility.* New York: Cambridge University Press.

help them understand how to convey useful scientific information in a wide range of political settings. For example, if a scientist can present information that leads prospective learners to understand that they have more shared values with others than they previously thought, the science can be an important component of collective decisions that improve quality of life.[35]

While much of what we consider political is a product of value diversity, diverse societies can come to realize that certain actions produce widely valued benefits. When such realizations emerge, so can broad-based agreements on the value of science in public decision making. When it can be demonstrated that what a certain audience does not know is preventing a broadly valuable competence from occurring, a sweet spot for science educators and communicators can emerge. This sweet spot entails identifying information that is not only necessary or sufficient to increase the competence, but also sufficiently beneficial to gain needed attention from prospective learners with particular sets of values. That is, it is not enough for the information to be factually accurate. To obtain the attention and credibility that increasing knowledge or competence requires, the information must reflect the common interests that exist within the diverse group. With such insights, there is greater scope science educators and communicators to increase valuable competences in increasingly bigger tents. When this happens, greater knowledge of relevant science becomes produces higher quality decisions that can improve the health of democracies, broadly defined.

In sum, science literacy matters for public participation in a healthy democracy when individuals involved in decision making processes recognize that the accurate and reliable insights that can come from applications of the scientific method can help them manage their challenges and opportunities more effectively or efficiently. Science is more likely to play this role when reconciling decision makers' beliefs to the best available logic and evidence is an antidote to the kinds of self-serving myths, speculations, and wishful thinking that often characterize public debate. Science literacy matters most to public participation in a healthy democracy when scientifically validated findings are necessary or sufficient for decision makers to achieve their highest-value aspirations.

IV. ANALYSIS: Evidence of Relationships Between Science Information, Decision Relevant Attitudes, and Attempts to Promote Civic Engagement and Increase Public Participation in Decisions

There is an academic literature on what kinds of information and education increase the extent to which people engage in various kinds of civic life. Most of this literature does not focus on science literacy per se. There are many public efforts to increase certain types of civic engagement, and some use science education as a means of achieving this goal. Many of these efforts are not rigorously evaluated. In many cases, outcome measures are anecdotal or appear

[35] See, e.g., Rupert Brown and Miles Hewstone. 2005. "An Integrative Theory of Intergroup Contact." In Mark P. Zanna (ed.). *Advances in Experimental Social Psychology*. London: Elsevier Academic Press, 256–345. These scholars describe research on the contact hypothesis that sometimes produces stirring examples of such changes.

to involve selection on the dependent variable (focusing on successes, while ignoring failures). Hence, in the period of time that I worked on this paper, I found no substantial scientific literature that directly addresses the panel's question *"Is there evidence that enhancing science literacy at the individual level changes civic engagement at the societal level?"*

That said, there are literatures on

- how different kinds of scientific information affect decision-relevant attitudes, and,
- what kinds of information and incentives increase civic engagement.

In each of these literatures there are insights that can clarify the kinds of information that lead people to become more engaged and active in decision making processes. I organize the remainder of this section with respect to the two types of content.

A. How Scientific Information Affects Decision Relevant Attitudes

Given the relationship between scientific research on climate and its political implications, many empirical studies of relationships between scientific knowledge and public decision making focus on the topic of climate. While many members of the scientific community assume that public ignorance of scientific information about climate science leads citizens to doubt climate science and deny its relevance, recent research has shown a different relationship between such knowledge and decision relevant attitudes.

A series of papers by Dan Kahan and his coauthors best exemplifies these findings. In "The Polarizing Impact of Science Literacy and Numeracy on Perceived Climate Change Risks", for example, Kahan et al demonstrates that people with higher levels of science literacy were only more polarized on climate change, and not more likely to be concerned about climate change.[36] In particular, they find:

> "Seeming public apathy over climate change is often attributed to a deficit in comprehension. The public knows too little science, it is claimed, to understand the evidence or avoid being misled. Widespread limits on technical reasoning aggravate the problem by forcing citizens to use unreliable cognitive heuristics to assess risk. We conducted a study to test this account and found no support for it." Kahan et al (2012): 732.

Instead of finding a positive association between scientific knowledge and concern about climate change, they found a strong and positive association between scientific knowledge and a tendency to express extreme points of view about the manner. In other words, highly knowledgeable citizens are more likely to express strong views about climate change, but these

[36] Dan M. Kahan, Ellen Peters, Maggie Wittlin, Paul Slovic, Lisa Larrimore Ouellette, Donald Braman and Gregory Mandel. 2012. "The polarizing impact of science literacy and numeracy on perceived climate change risks." *Nature Climate Change* 2: 732-735.

views are not always those that political liberals would recognize. As Kahan et al (2012:732) conclude "Members of the public with the highest degrees of science literacy and technical reasoning capacity were not the most concerned about climate change. Rather, they were the ones among whom cultural polarization was greatest."

There are many cases where either a fear of science or a fear of thinking scientifically, gives people a strong incentive to make decisions based on factors other than science.[37] In such cases, unless it can be demonstrated that ignorance of particular scientific principles is directly responsible for these people's inability to achieve important aspirations, there will be little demand for science literacy. With such dynamics in mind, Kahan et al offer advice to science communicators and science educators that also reflect themes developed in Section III above. Their advice is as follows:

> "[C]ommunicators should endeavor to create a deliberative climate in which accepting the best available science does not threaten any group's values. Effective strategies include use of culturally diverse communicators, whose affinity with different communities enhances their credibility, and information-framing techniques that invest policy solutions with resonances congenial to diverse groups. Perfecting such techniques through a new science of science communication is a public good of singular importance." Kahan et al (2012:734).

Stem cell research is another issue with a strong scientific pedigree and increasing political attention. Nisbet's (2005) work starts from a similar starting point as Kahan's and anticipates his subsequent results. Like Kahan et al, Nisbet (2005: 90) argues:

> "When it comes to public opinion about controversial issues related to science and technology, many policy makers and scientists assume that increased public understanding of science will lead to increased public support…[T]his study tests the relationship between an increase in available information – or increasing 'awareness' – and public support for embryonic stem cell research…[A]lthough an increase in awareness leads to an increase in support for research, both religion and ideological value predispositions strongly moderate the impact of awareness."[38]

As previewed in Sections II and III above, the value of increased scientific knowledge to citizens depends on their values and what they perceive they can do with the information. For people whose values and preferences support the general idea of inquiries to the possible health benefits of stem cell research, the addition of scientific information clarifying these benefits

[37] For a review of recent research and literature review on this topic, see Elizabeth Suhay and James N. Druckman. 2015. "The Politics of Science: Political Values and the Production, Communication, and Reception of Scientific Knowledge." *The Annals of the American Academy of Political and Social Science* 658: 1-306.

[38] Matthew C. Nisbet. 2004. "The Competition for Worldviews: Values, Information, and Public Support for Stem Cell Research*." International Journal of Public Opinion Research* 17: 90- 112.

leads to more effective and efficient pursuit of shared goals. For people whose values and preferences are threatened by human interference in these cell-level processes, further research not only has little value but is something that they could be convinced to organize against.

Vaccination is another increasingly prominent issue at the science-civic nexus. Much of the controversy stems from media coverage and celebrity endorsements of a since retracted and discredited study of vaccines and autism. Many health professionals and others are concerned that the spread of such information will produce lower vaccination rates – which could cause substantial new risks to public health. In response, many individuals and organizations have sought ways to increase public support for vaccination through education campaigns.

Political scientist Brendan Nyhan has conducted a number of highly informative studies on this topic. His initial research gives an overview of attempts to correct misinformation in politicized environments. Nyhan and Reifler (2010), for example, vary the content of news articles and then randomly assigned the different versions to undergraduate experimental subjects.[39] Over a number of issues they find that attempts to correct misinformation fail to reduce misperceptions that are favored by the subject's partisan group. They also find that *attempts to correct errors increase misperceptions amongst such audiences* – with the lack of effect particularly strong for whoever's partisan ox is being gored.

The misinformation studies in the public health domain use many of the same methods, but reach different audiences. In the 2014 *Pediatrics* article, Nyhan and his coauthors randomly assigned over 1700 US parents to experimental treatments that differ in the information that they offer about the MMR vaccine.[40] Some received information about the lack of evidence connecting the vaccine to autism. Others received information about the dangers of MMR. Others see dramatic images or narratives about young MMR patients. A control group saw no such content. The main finding is that while the corrective information decreased belief that the MMR vaccine causes autism, none of the interventions increased intent to vaccinate. Moreover, subjects who were given the narratives and images of MMR patients without the corrective information were more likely to link vaccines to autism, while subjects who received corrective information were significantly less likely to vaccinate than the control group. This study is important as it counters several lines of argument about how to increase vaccinations. The combination of design and result is attracting significant attention and has the potential to transform how many people in the health and medical fields think about communicating critical information to broad audiences.

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[39] Brendan Nyhan and Jason Reifler. 2010. "When Corrections Fail: The Persistence of Political Misperceptions." *Political Behavior* 32: 303-330.

[40] Brendan Nyhan, Jason Reifler, Sean Richey, Gary L Freed. 2014. "Effective Messages in Vaccine Promotion: A Randomized Trial." *Pediatrics* 133: e835-e842.

In the 2015 *Vaccine* article with Jason Reifler, Nyhan uses an experiment to demonstrate that offering corrective information to the belief that the flu vaccine can give recipients the flu made people less likely to retain the false belief.[41] The more interesting result, in my view, is that the same stimulus reduces intent to vaccinate for people who were highly concerned about vaccine side effects. One way to interpret the result is that the corrective information induces some people with significant qualms about side effects to search their memories for other information that would reinforce their qualms, that such an effort would remind people of other possible side effects and reduce vaccination. This finding is important because the "corrective" approach is often advocated by public health interest groups

In all three areas, scholars are finding that increasing exposure to scientific information does not necessarily lead to increasing support for more research or for science to have greater influence in policy domains. When citizens see science as helping them more effectively and efficiently accomplish tasks that are consistent with their shared values, there is greater interest for having more people learn more about science and greater support for reconciling policy with scientific findings.

B. Information, Incentives and Civic Engagement

I will review two types of studies on how changes in available information affect civic engagement. First, I will review empirical research on this topic. The empirical research tends to focus on populations that are seen as being less participatory than average. Next, I will review claims made in the context of large-scale attempts to improve civic engagement. This latter research tends not to have attributes that would describe rigorous peer review and will be described accordingly.

There is a long tradition of research in political science on participation. For most of the 20th century the literature was descriptive. In the 1970s and 1980s the literature took a quantitative turn.[42] At the beginning of the 21st century, scholars began to use many different kinds of field experiments to document conditions under which varying presentations of information could produce increases in subsequent behavior.[43]

Prior to the advent of the experimental work, education, income, home ownership, length of time living in a particular community, trust in government and a sense of political efficacy were consistently found to have among the strongest associations with many kinds of civic

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[41] Brendan Nyhan and Jason Reifler. 2015. "Does Correcting Myths About the Flu Vaccine Work? An Experimental Evaluation of the Effects of Corrective Information." *Vaccine* 33: 459-464.

[42] For a review of this literature, see Cliff Zukin, Scott Keeter, Molly Andolina, Krista Jenkins, Michael X. Delli Carpini. 2006. *A New Engagement? Political Participation, Civic Life, and the Changing American Citizen*. New York: Oxford University Press.

[43] See, e.g., Alan S. Gerber and Donald P. Green. 2012. *Field Experiments: Design, Analysis, and Interpretation*. New York: W.W. Norton and Company and James N. Druckman, Donald P. Green, James H. Kuklinski, and Arthur Lupia. 2011. *The Cambridge Handbook of Experimental Political Science*. New York: Cambridge University Press.

engagement. Much of these effects was due to variance at the lower end of the respective scales. For example, for individuals with sufficiently low income and education, matters of survival and subsistence often take priority over political participation. People don't participate because they may lack resources, lack psychological engagement with politics, or be outside of the recruitment networks that bring people into politics. This is particularly true for types of participation that required some degree of advance planning (such as registering to vote) or personal transportation (needed to attend educational activities or civic gatherings).[44]

There is also issue-specific participation. Some citizens are single-issue voters. They are very passionate and informed about a particular issue, such as farmers and agriculture policy, steelworkers and trade policy, or people from particular religious traditions and abortion. If an election or policy debate relates to these issues, these individuals mobilize and participate. Otherwise, they are content to play less of a role.[45]

Other research focuses on specific populations. For example, Berry and Junn (2015: 580) find a strong association between education level and political participation for prominent ethnic minority groups. They conclude that "for both Latinos and Asian Americans, rates of participation increase significantly with level of education…. it is the most impactful resource for both groups. It … has nearly twice the impact on participation for Latinos as it does for Asian Americans."[46]

Political scientists Richard Niemi and Michael Hanmer (2010). Have studied ways to encourage college students to be more civically engaged .[47] These scholars conducted a phone survey of college students. They found:

> "The usual demographic factors were of little relevance. Only gender was important, with college women voting at a higher rate than college men. Motivational factors and mobilization, in contrast, operated in the same way as with other adults. Students interested in politics, and those with strong partisan feelings, registered and voted in greater numbers. Those who were contacted by the parties—a surprisingly large

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[44] See, e.g., Zukin, et al (2006); Nancy Burns, Kay Schlozman, and Sidney Verba. 2001. *Private Roots of Public Action*. Cambridge, MA: Harvard University Press; and Kate Kenski and Natalie Jomini Stroud. 2006. "Connections between Internet use and Political Efficacy, Knowledge, and Participation." *Journal of Broadcasting and Electronic Media* 50: 173-192.

[45] See, e.g., Edward G. Carmines and James A. Stimson. 1980. "The Two Faces of Issue Voting." *American Political Science Review* 74: 78-91.

[46] Justin Berry and Jane Junn. 2015. "Silent citizenship among Asian Americans and Latinos: Opting Out or Left Out?" *Citizenship Studies* 19: 570-590.

[47] Richard Niemi and Michael Hanmer. 2010. "Voter Turnout among College Students: New Data and a Rethinking of Traditional Theories." *Social Science Quarterly* 91: 301-323.

> proportion—voted more often…Transferring between colleges suppressed turnout, and students majoring in math, science, and engineering voted less often."

Related research points to the importance of early childhood socialization as a driver of adult political participation. Niemi and Klingler (2012), for example, conclude that

> "the university experience does not socialise students to adopt higher levels of political participation than that exhibited by their peers not in school. University students begin early adulthood with higher levels of participation than non-university students, but their participation is not enhanced while they are at university."[48]

A Swedish study reveals a similar dynamic:

> "This article utilizes a Swedish panel survey to gauge whether there is a direct causal link between type of education and political participation. Results demonstrate that differences in political participation are already present when students enter different types of education. The analyses show no significant effects of education; instead results support the education-as-a-proxy view: pre-adult factors predict political participation as well as educational choice."[49]

So, scholars have struggled to identify a relationship between college attendance and civic participation that is not, itself, differentiable from various selection biases. These studies, however, reflect attempts to find broad statistically significant patterns across different types of educational programs. When specific programs are evaluated, we can identify patterns in activities that work more and less well. Consider for example, the finding of Stroup et al (2013: 116).[50]

> "We used a staggered implementation design in which eight classes of traditional first year college students in were taught a political engagement curriculum by two instructors. The results confirm the positive impact of the political engagement curriculum above and beyond a rhetoric and composition curriculum for traditional first-year college students on important political indicators such as internal political efficacy and attentiveness and interest in politics. Further, participants exhibited significant post-intervention differences with regard to their comfort level joining political conversations as well as employing important conversational strategies to strengthen

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[48] Richard Niemi and Jonathan Klinger. 2012. "The Development of Political Attitudes and Behavior Among Young Adults." *Australian Journal of Political Science* 47: 31-54. Also see Meghan Condon. 2015. "Voice Lessons: Rethinking the Relationship Between Education and Political Participation." *Political Behavior* 37: 819-843.

[49] Mikael Persson. 2012. "Does Type of Education Affect Political Participation? Results from a Panel Survey of Swedish Adolescents." *Scandinavian Political Studies* 35: 198-221.

[50] John T. Stroup, Hadley Bunting, Kyle Dodson, Miriam Horne & Julian Portilla. 2013. "Promoting a Deliberative and Active Citizenry: Developing Traditional First Year College Student Political Engagement." *College Teaching* 61: 116-126

> democratic dialogue. These results support the use of this curriculum to increase first year college students' political engagement and underscore the impact that classroom curriculum and instruction can have promoting a deliberative and active citizenry."

Indeed, this study reflects a broader set of findings that are changing educational strategies in many areas. Where civic education has often been characterized as rote memorization of certain historical and institutional facts, increasing numbers of studies show that more interactive forms of learning produce better learning outcomes. In the context, of civic education, this means that more participatory civic educational experiences can produce more participatory citizens.[51]

Many organizations develop similar programs. Few appear to rigorously evaluate the effect of their interventions. There are, for example, few random controlled trials in this space. I close this subsection by describing a few of these efforts. [52]

The Participatory Budgeting Project (PBP) is a non-profit organization that partners with local governments to involve citizens in decision-making processes around how to spend public money. Their mission is to "create and support participatory budgeting processes that deepen democracy, build stronger communities, and make public budgets more equitable and effective." In its 2013 year-end report on intervention(s) in New York City (page 16). PBP reports that "38% of neighborhood assembly participants and 50% of PB voters had never worked with others in their community to solve a problem before PB; an increase from Year 1 where a third of neighborhood assembly participants and 44% of PB voters had never worked

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[51] Also see The Andrew Goodman Foundation. 2015. *Vote Everywhere*. Available at: https://andrewgoodman.org/wp-content/uploads/Vote-Everywhere-Impact-Fall-2015.pdf

[52] The Case Foundation. 2015. *Cause, Influence, and the Next Generation Work Force: The 2015 Millennial Impact Report*. Available at: http://www.themillennialimpact.com/files/2015/07/2015-MillennialImpactReport.pdf. The Case Foundation is seeking ways to increase civic engagement among millennials. Its focus is on young professional and on the extent to which they can be induced to volunteer for social causes and making monetary contributions to charity. Case claims empirical success with a number of approaches. One is peer leadership.

> "We found that peers and direct co-workers are the most likely individuals to influence Millennial employees to participate in company cause work. Managers also influence participation, and direct managers carry much more influence than higher-level executive employees. 27% of Millennial employees said they are more likely to donate to a cause if their supervisor does; while 46% of employees are likely to donate if a co-worker asks them to. Interestingly, only 21% of Millennial employees said they are more likely to make a donation if the CEO or a top-ranking executive asks them to." (p. 6)

Another is competition: "Millennial employees, in particular, respond to incentives and competitions as motivators. While they are often interested in and even passionate about a cause, cultivating a sense of competition around a giving campaign or volunteer project through promotions will increase involvement. Tangible incentives such as name recognition, prizes and additional time off will encourage Millennial employees to participate." (p. 6) with others in their community to solve a problem before PB."[53] By 2015, the organization reports that "a third of active participants reported participating more in local organizations after PB."[54]

Organizations such as Demos and Project Vote have conducted studies on the relationship between same-day registration and civic participation in elections. This work is relevant because states vary in their requirements for voting on Election Day. Some states require registration far in advance of Election Day. Citizens who do not register in time in such states have less incentive to engage in election-relevant civic debates. Other states allow same-day registration. Demos finds that voter turnout in same-day registration states are over seven percentage points higher, on average, than other states.[55] Project Vote, in a more recent study, finds a ten-point differential.[56] These studies provide some evidence about the importance of structural factors in promoting or inhibiting an important form of civic participation.[57]

C. Summary

The world has changed. Until the Internet made massive amounts of information storage and retrieval widely available, people who wanted to access scientific information had a limited number of ways to proceed. Children could learn about science in schools, where science education became an increasing priority as the 20th century progressed. Adults had additional options, though for most these opportunities were limited in number and quality. They could visit bookstores (which tended to be small) or local libraries, most of which had very limited collections of print-based scientific publications. They could read the few widely available science-oriented magazines or attend to the few radio/television programs that contained small amounts of information about science. Some could attend colleges or universities (though women and non-whites were less likely to do so for most of the 20th century). At colleges and universities, students tutelage from faculty who, while expert in their subject area, relied heavily on anecdotes and experience when forming beliefs about the most effective ways to convey scientific information to others.

[53] *A People's Budget: Year 2: A Research and Evaluation Report on Participatory Budgeting in New York City*. 2013. Urban Justice Center and the PBNYC Research Team. Available at: https://cdp.urbanjustice.org/sites/default/files/pbreport_year2_0.pdf

[54] *Participatory Budgeting in North America: 2014-2015: A Year of Growth.* 2015. Brooklyn: Participatory Budgeting Project. Available at: http://www.participatorybudgeting.org/wp-content/uploads/2015/07/PBP_Report_2015_Printing.pdf

[55] Demos. 2010. *Voters Win with Same Day Registration: A Demos Policy Brief.* New York: Demos.

[56] Project Vote. 2015. *Same Day Registration: Project Vote Factsheet*. Washington DC: Project Vote.

[57] Everyday Democracy is another organization that seeks to improve public participation through large scale participatory interventions. See http://www.everyday-democracy.org/about-national-movement.

In the pre-Internet era, people who wanted information about many of the things that scientists study had to come to us. Science communicators were a few in number and many were in a monopolistic or near-monopolistic position in the market for information on the topics of their expertise. Absent competition, many scientists came to believe that those who read our books or attended our lectures were obligated to sit our presentations regardless of their quality. We came to believe that others were obligated to learn about abstractions that they could never use as the price to be paid for obtaining from us small amounts of knowledge that they might be able to use. In the absence of communicative competition, in the absence of accurate measures of our communicative effectiveness, our audiences had little or no recourse when offered ineffective information. At the same time, individual scholars and many scholarly organizations had no incentive to change how they think about and evaluate the effectiveness of their communicative efforts.

The world has changed. Now there are multiple sources of information on many of the topics for which science and scientists wish to be influential. Moreover, it is safe to assume that we are closer to the beginning of this information revolution than we are to the end. On many topics, journalists and bloggers have fast access to unprecedented amounts of information from which they can derive explanations of topics also covered by science. The number of ways in which people can store and access information continues to grow. As a result, the number, reach, and sophistication of individuals and organizations who seek new and evolving communicative mediums to seek and deliver scientific information is likely to grow.

For people and groups who remain committed to evaluating propositions and grounding knowledge claims in the scientific method, our long-standing expectations about the demand for scientific knowledge and its role in public decision making are under unprecedented pressure. Audiences to whom we seek to provide value by offering knowledge claims with demonstrably high truth-value have fast evolving expectations about how information should be conveyed. Communicative formats that people once had to endure due to lack of competition can now be bypassed or ignored. For scientists and science to remain relevant and influential in the public sphere, science communicators must become more skilled a finding the intersection between the knowledge they create and audience attributes that will lead them to pay attention to -- and learn -- the content.

The literatures reviewed up to this point reveal circumstances under which decision makers will be more (and less) interested in learning more about science. In addition to committing to communicate scientific information in ways that people will want to use. That is, information that is consistent with perceptions of increasing efficacy as seen from the perspective of shared values and associated tasks that decision makers see as important to complete. One advantage that science retains in many such circumstances is that it is widely trusted. As Nisbet and Markowitz (2016) report:[58]

[58] Matthew C. Nisbet, and Ezra Markowitz. 2016. *Science Communication Research: Bridging Theory and Practice.* Commissioned Synthesis and Annotated Bibliography in Support of the Alan Leshner Leadership Institute American Association for the Advancement of Science.

The good news for the scientific community is that among U.S. institutions, scientific leaders tend to hold very high levels of trust. In 2012, 90 percent of the public expressed either “a great deal of confidence” (41%) or "some confidence" (49%) in leaders of the scientific community. In comparison, since the 1970s, as public confidence in Congress, the presidency, industry, religious institutions, and the news media have plummeted; public faith in the scientific community has remained virtually unchanged.[59] Some evidence suggests that trust in the scientific community has declined among conservatives, though other research indicates that conservatives tend to be more skeptical of so-called "impact scientists," researchers such as climate scientists or health scientists who examine the environmental and health impacts of economic development and technology. In contrast, conservatives tend to hold greater trust in so-called "production scientists," researchers such as engineers or chemists producing new technologies and marketable products.[60]

This trust is a key to continued public influence. However, increasing politicization and incentives to exaggerate or misrepresent science for the purpose of advancing particularistic agendas remains as a threat to public perceptions of science’s trustworthiness. For this reason, the movement for greater transparency within the broad scientific community is critical for maintaining that trust. Scientists cannot control what lobbyists and other entrepreneurs say about science, but it can regulate the types of claims that active researchers make in science’s name. When citizens are in situations where they recognize the potential value of science, or when they are in situations where science can clarify important consequences about complex topics, researchers ability to increase civic engagement and improve the quality of public participation is to meet citizens’ expectations of our trustworthiness by conducting ourselves in ways that are worthy of that trust.

V. CONCLUSION

Science has done so much to improve quality of life for people around the world. Yet, science’s ability to have these effects depends on the extent to which key decision makers understand relevant science and how it pertains to their circumstance. This paper examined what kinds of “science literacy” are most valuable to prospective learners and sought to clarify the kinds of strategies that are most likely to cause prospective learners to more effectively engage in critical public decisions. While there is no knowledge base that addresses all aspects of the panel’s inquiry simultaneously, there are a number of scholarly endeavors that can contribute to science playing a more valuable role in civic engagement and public discourse. By developing

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[59] Matthew C. Nisbet, and Ezra Markowitz. 2016. *American Attitudes about Science and Technology: The Social Context for Communication*. Commissioned report prepared for the Alan Leshner Leadership Institute of the American Association for the Advancement of Science, Washington, DC.

[60] Aaron M. McCright, A. M and Riley E. Dunlap. 2010. “Anti-reflexivity the American conservative movement’s success in undermining climate science and policy.” *Theory, Culture & Society* 27: 100-133.

“literacy” and “engagement strategies that convey the most important elements of the most relevant science to people who are willing and able to use it, science educators and science communicators can more effectively provide information to situations in which it can have the greatest effect on public decision making. The existing literature clarifies situations where people will value the information. If we in the science community can do a better job of recognizing these situations, we will be in a better position to give people information that they can use to manage threats both man-made and natural and to achieve substantial improvements in quality of life for people around the world.