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A Sociologically Informed Ethics of American Science Literacy: Toward a Transdisciplinary Understanding

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Abstract

This paper reexamines the ethics of improving public knowledge about science and technology, or science literacy. Rather than reproduce the core themes of the large body of literature on this topic over a number of decades, this paper uses National Science Foundation's Science and Engineering Indicators for the 10-year period 2002-2012 to inform a transdisciplinary analysis of knowledge production, and kinds of science knowledge produced. In particular, the paper highlights the need to identify different sub-publics, understand their value systems and the socio-cultural contexts in which they operate, and how these publics are not simply passive consumers of knowledge, but are themselves co-producers and appliers of science related knowledge. The paper thus argues for an ethics of scientific literacy that takes account of knowledge production beyond disciplinary and interdisciplinary frameworks, and uses this understanding to foster an authentic deliberative partnership of engagement.

Keywords: Science literacy; Science ethics; Transdiscipliarity; Deliberative engagement

Introduction

Brey has argued that complex social problems require an interdisciplinary philosophy and an ethics of science, not least because these problems "do not obey disciplinary borders and by nature require interdisciplinary collaboration" [1]. However, disciplinary myopia does not necessarily lead to interdisciplinary integration.

Alternatives approaches are:

(1) multi-disciplinarity, which retains the depth of disciplinary integrity without compromising its range and breadth, but neither integrates knowledge nor includes knowledge outside of disciplines; and (2) Transdiscipliarity, which challenges the assumption that organized disciplinary knowledge is sufficient for a comprehensive understanding of complex phenomena, and points to the limits of multi-disciplinarity and interdisciplinarity because they remain in the domain of organized academia. Indeed, interdisciplinarity excludes informal and spontaneous knowledge production, local knowledge, folk wisdom, indigenous knowledge, and experiential knowledge that Carp calls multiple "knowledge formations," which "are both bodies of knowledge and processes of coming to know that contain within themselves dynamic patterns from which they have been generated and by which they will be transformed" [2]. Others have referred to such knowledge formations and their embodied praxis, as transdisciplinarity.

Transdiscipliarity goes beyond the boundaries of existing disciplines and "concerns that which is at once between the disciplines, across the different disciplines, and beyond all discipline. Its goal is the understanding of the present world, of which one of the imperatives is the unity of knowledge [3-4]. It thus concerns knowing who the knowledge creators are and who are the partners in different k inds and levels of knowledge production. This necessarily involves knowing their identities in socially constructed networks; in short, what it is to become transdisciplinary [5]. In this paper we apply one version of transdiscipliarity to the ethics of scientific literacy.

Innovations in science and technology pose ethical issues for society as students and scholars of the public understanding of science and technology have long been aware. Opinion polls in the United States have consistently found that the vast majority (84-90%) of the American public likes science, trusts and values scientists and believes science has a positive effect on society [6-9]. Indeed, "Surveys since at least 1979 show that roughly 7 in 10 Americans see the effects of scientific research as more positive than negative for society." In 2012 this included "50% who said they believed the benefits "strongly" outweigh the negatives, and 22% who said the benefits slightly outweigh the potential harms. Perhaps not surprisingly, this finding is correlated with level of education, such that 55% of those completing only high school education believe science does more good than harm, compared with "89%" of those with bachelor's degrees and 92% of those with graduate degrees [10].

However, it is important to note that for science in Western cultures and, in the US in particular, "a sizeable fraction of the public is willing to believe that the scientific community is engaged in a nefarious plot to deceive them" [11]. Although the 2012 NSF survey found that only "about 7% said science creates more harms than benefits", a 2010 survey by the International Social Survey Program found that 14% of Americans said that "modern science does more harm than good"[12]. Indeed, "a sizable segment of the U.S. population" holds some reservations about the relative importance of science and technology and whether it is sufficiently ethically grounded. In a 2004 study, "more than half of the respondents agreed that 'we depend too much on science and not enough on faith,' that 'scientific research these days doesn't pay enough attention to the moral values of society,' and that 'scientific research has created as many problems for society as it has solutions'[7,8]. Indeed, one survey of the American public found that "a majority (56%) agrees that scientific research doesn't pay enough attention to the moral values of society" [9]. In 2010, "41% of U.S.

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residents" stated that "we believe too often in science and not enough in feelings and faith".

A Pew study also found a degree of mutual suspicion, with scientists giving an unfavorable assessment of the public's knowledge of science, 85% of whom "see the public's lack of scientific knowledge as a major problem for science" [6]. Moreover, scientists blame the media for failing to adequately educate the public, with 76% saying that news reports fail to distinguish between good and bad science, and that many reports oversimplify scientific results; indeed, 83% of scientists rate TV news coverage of science as poor [6].

However, this may change as the American public expands the sources it relies on for science information. In 2008 surveys revealed that television was the major source of news about science at 41% (down from 44% in 2001) citing this as their primary source. But by 2012, the Internet had overtaken television as the primary source: "42% of Americans cited the Internet as their primary source" of science and technology knowledge information, "up from 35% in 2010," with primary reliance on television dropping to period after 32% [10].

Over the years there have been various calls for improvements in the relationship between science and the public through a "stepping-up" of what is variously described as "approval, appreciation or understanding of science by the public [13]". In order to improve public understanding of science, it has been recommended that scientists should better communicate with the public. The idea of improving public knowledge through communication about science and technology, or improved "scientific literacy," is not new and has produced a large body of literature over several decades.

But first it is important to know what we mean by scientific literacy. The Organization for Economic Cooperation and Development defines scientific literacy as "the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity [14]". We prefer the National Science Foundation's definition of science literacy: "knowing basic facts and concepts about science and having an understanding of how science works [7]". But, what are the ethics of science communication and what are the ethics of science literacy? If, as has been argued, the work of ethics is integral to the daily work of science [15], what are the ethical dimensions involved in the process of improving the public's knowledge and understanding of science?

Clearly this depends, in part, on: (1) the goals and objectives of such communication, (2) the kinds of knowledge drawn on, and (3) the ways that knowledge is used to meet these goals. As public sociologists we believe that it is important to ground the concepts we advocate in the activities that we practice. In this article, then, we are interested in the kinds of knowledge that are necessary in order to ensure that science communication is ethically grounded. We argue that an awareness of the ethical issues of effective public engagement with science is important to policymakers, public advocates, and academics, but that such grounding depends upon the incorporation of a variety of understandings that derive from different disciplinary and non-disciplinary knowledge sources and sites.

In this paper, then, we summarize some of the key issues relating to the ethics of science literacy including: (1) scientists' political reasons for educating the public, (2) the social stratification of knowledge about science, (3) the differentiation of kinds of knowledge about science, (4) the appreciation of multiple social audiences that make up "The Public," (5) effective strategies that must take account of these socio-political dimensions in order to ensure an ethical basis for the "public" understanding and civic partnership with science, and, (6) knowledge of the political and policy-making process that is necessary in order to understand how improved scientific literacy grounded in transdisciplinary knowledge about the sociological, political and ethical implications of science, can translate into public policy.

Thus, we argue that in order to maintain an ethical basis for science communication aimed at improving public science and health policy, it is necessary to adopt a transdisciplinary approach to science literacy that takes account of the social-political organization of society, marginal knowledge production from outside formal disciplines, and varieties of scientific literacy, that relates to the public's effective participation in public policy. We need to know: (1) what kinds of science literacy are important for people who are members of differentiated publics, and (2) how to make meaningful decisions about new developments in science and technology?

It is important for the public to understand the scientific process, and it may be that they need an ability to remember factual information about new technologies. However, as Wynne has argued in examining the local filtering of scientific knowledge in the case of Chernobyl, "the social relationships and identities which people feel to be affected by scientific knowledge" makes a difference to its understanding [16].

As we argue below, rather than having improved knowledge about science, it may be more important for a public to have: (1) a contextualized and localized knowledge, (2) non-disciplinary knowledge that takes account of the socio-political context and socially constructed identities, and (3) an articulation of perceived relationships with experts involved in science policymaking. Indeed, perhaps even more important than scientific knowledge, or "issue specific political knowledge" may be: (1) the influence of religious and ideological values, particularly those advocating against science (e.g. Boko Haram), and (2) mass media framing of science literacy and its manipulation, which as Nisbet and Goidel [17] demonstrated was critical in the case of embryonic stem cell research, and Oreskes and Conway[18], showed was also operative through the "merchants of doubt" in denying the existence of global warming.

Why is it Important for the Public to Understand Science and Technology?

Scientists have assumed that increased public knowledge of science is good for humanity and that scientists communicate because of their exuberant enthusiasm to share their excitement about their field. However, Miller and Gregory [13,19] have pointed out, there are multiple and often political motives for scientific communication including: "to empower its recipients, to enhance existing democratic processes or help develop new ones where they do not exist, or to prevent the alienation of sections of society; but it may also be to serve the interests of the scientific community and their paymasters."

Government institutions and agencies are seen as the most important funding source for science, according to 84% of scientists [6]. As a result, increased public knowledge about science is seen as important for legitimating the continuing funding of science by policymakers. From this perspective Nisbet [20] has argued that a commonly held assumption is that "civic science literacy boosts the cultural authority of science." Thus, "if the public knew more about science, then scientists would have greater influence over important policy decisions." As a result, "most public understanding of science activities are aimed at improving civic science literacy [20]". Indeed, Nisbet cites a British government report stating that there is a "false assumption that any difficulties in the relationship between science and society are due entirely to ignorance and misunderstanding on the part of the public; and that, with enough public-understanding . . . the public can be brought to greater knowledge, whereupon all will be well [20]".

Sociological Insights

Importantly, these political motives are based on a variety of sociological assumptions about: (1) producers and receivers of knowledge, (2) the value of certain kinds of knowledge to society, (3) the ways scientific knowledge will be used in the social order, (4) about who benefits, and how, from its use. For example, reliance on scientific knowledge to guide improving public health can lead to an emphasis on lifestyle at the expense of considering political and socioeconomic factors such as poverty, the environment and the societal systems that produce them [21]. In order to avoid scientific knowledge replicating the harm currently produced by existing social structural arrangements, a sociological knowledge of the role of the power-knowledge nexus is necessary. The point here is that improving public scientific knowledge does not have a universally positive effect, but impacts some sections of society more than others. Moreover, improving scientific literacy, by virtue of the uncritical way it is perceived, is not the same as an enlightened public empowered to make ethical and substantial decisions about the value of scientific research, the importance of scientific and technical innovations, or the need to implement health practices and policy. Understanding how empowerment of the public can mediate the production and dispersal of knowledge in ways that benefit society requires a sociological knowledge of the process of science as a resource. It also requires that we recognize and value the experiential and subject position knowledge of non-scientists in this process as co-producing partners rather than passive recipients of some greater good. This transdisciplinary contribution is crucial to a more comprehensive understanding of science.

A Transdisciplinary Theoretical Framework

We ground our analysis of the ethics of science literacy in the expansive approach to knowledge production, formation, and praxis referred to as "transdisciplinarity." This approach incorporates both disciplinary knowledge and non-disciplinary knowledge, i.e. knowledge production by sources that lie outside of disciplinary knowledge sites [2-4]. This i ncludes p ublic k nowledge, a nd k nowledge g enerated b y non-professional partners, collaborators, stakeholders, and others such as community groups and those impacted by the applications of science. However, transdisciplinarity has several definitions. For some it means "the application of theories, concepts, or methods across disciplines with the intent of developing an overarching synthesis [22]", aimed at "answering a complex question, solving a complex problem or producing new knowledge or a product [23]". Repko elaborates, citing sociobiology's evolutionary theory as an example of transdisciplinarity: "Transdisciplinarity differs from interdisciplinarity in that the theories, concepts, or methods are not borrowed from one discipline and applied to other disciplines interested in the same problem, but rather transcend disciplines and are therefore applicable to many fields [24]". McGregor defines trans disciplinarity as "crossing back and forth and moving along and beyond sectoral boundaries" which includes trans disciplinarity as a methodology for knowledge creation [25] and, indeed, for Nicolescu it involves reconceiving of knowledge and realty such that reality is plastic and knowledge is alive and emergent[4]. Indeed, for some such "living knowledge" is also transformational of the producers and those who engage it [26].

This glimpses a second meaning of transdisciplinarity which moves beyond the disciplines to other forms of knowledge production and explores how to begin to integrate these into the totality of explanation for social action. Since mega and complex problems, such as health and wellness require comprehensive policy and practice involving collaboration among a hybrid mix of actors from different disciplines, professions, and sectors of society this version of transdisciplinarity necessarily involves multiple knowledge producers and a "unity" of knowledge [23, 27]. For example, while universities generate disciplinary based knowledge, and to some extent interdisciplinary knowledge, the professions develop a practice-based knowledge and inter-professional knowledge [28]. We might then add lay knowledge, folk wisdom, experiential knowledge, spontaneous unorganized knowledge or what Carp summarizes as "the varieties of local, vernacular, or cross-cultural knowledge". This interpretation of transdisciplinarity includes knowledge production across all sectors and the knowledge formations that result. Thus transdisciplinarity, "unlike inter-disciplinarity, crosses both disciplinary boundaries and sectors of society by including stakeholders in the public and private domains [24]".

The reasons why scientists are interested in increasing public literacy about science become even more complex when the scientific topic is politically or religiously controversial as in, for example, genetically modified foods, stem-cell research, global climate change, or the borderless claims of fundamentalist Islamic ideology. For example, a Pew survey found that while 84% of scientists believe that global warming is the result of human activity, such as burning fossil fuels, just 49% of the public agrees. Even more divided are views over evolution in which 87% of scientists accept evolution as a result of natural selection, compared with 32% of the public [6]. Dacey points out that, "as science-related controversies emerge as sources of political contention, the public understanding of science becomes an increasingly important indicator of the public's competence to participate in policy decisions, and the health of civic culture [29]". However, in order to effectively participate in policy decisions involving science, the public needs to be competent in understanding not only the science, but also the politics involved in the public policy process; at very minimum they need to have knowledge of political science, sociology of organizations, and organizational psychology. In short, scientific literacy must include understanding sociopolitical literacy or else it is not literacy but knowledge in a vacuum.

Understanding the role of mass media in framing and engaging the public in science ethics is also important. Schäfer has argued that issues in science and technology from different epistemic cultures can be expected to be analyzed and debated in the mass media to different extents and that knowledge of media studies is critical to understanding the politics of science literacy [30]. This is particularly important in the context of the findings by Nisbet and Goedel that "religious and ideological values appear to filter the influence of information disseminated by scientific institutions," and that "attention to newspaper coverage, along with various forms of genre-specific entertainment television use, have unique influences on citizen evaluations, suggesting that the mass media provide an important part of the social context by which citizens judge controversial science".

So, if the public's scientific literacy is a measure of our cultural health and public competence to participate in a democracy, then the level of interest, extent of knowledge, and depth of understanding, are critical themes of this assessment, as is the extent to which scientists are committed to the expansion of this literacy. Indeed, from this perspective an investment in civic scientific literacy is the moral responsibility of the scientific community, and one, which they have largely embraced, albeit for the variety of political reasons identified above. But does the public want to be educated about science and, if not, is science education ethical? Moreover is the public's scientific literacy combined with an absence of sociopolitical awareness a case of a little knowledge being a dangerous thing?

How Interested are the Public in Science and Technology?

Surveys conducted by the National Science Foundation (NSF) and other organizations (e.g. Pew), repeatedly show that Americans are interested in issues regarding science and technology. The public's interest is particularly enhanced when the topic is new developments or discoveries. In NSF surveys conducted since 1979, "four out of five Americans say they are interested in new scientific discoveries". As well as being interested in science, it is important to know how the public values science, particularly in light of the more controversial areas of scientific research since, if they do not value science, they are unlikely to agree that it should receive public funds. Further, if they do not value science, is it ethical to attempt to persuade them to do so?

Does the Public see Scientific Research as Valuable?

Given the preponderance of public support for science's value, it is not surprising that the American public supports the funding of science. In fact, "All indicators point to widespread support for government funding of basic research" and about 4 in 10 Americans said the government was spending "too little on research [31]". In 2012, about half of respondents said government spending on scientific research was "about right," and about 1 in 10 said there was too much research spending. In 2001, 81% of the NSF survey respondents agreed with the following statement: "Even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the Federal Government." By 2012, these patterns remained the same: 83% of Americans "agreed" or "strongly agreed" with the same statement.

However, as the authors of the NSF study state: "a consistently small percentage of respondents have held the opposite view. In 2004, 17% disagreed with the statement; only 2% strongly disagreed with it". Other surveys reveal similar results with VCU's Science and Public Policy survey reporting that 82% of the public feel government support for science research is important compared with only 15% saying that it was not important [9]. How the public makes this assessment depends either on how much they know about science and/or how convincing are scientific communicators in convincing them of this value.

How Knowledgeable are the Public about Science and Technology?

While the general public's interest in science and technology is high, the number of people who feel either well-informed or moderately well-informed is reasonably low. In 2001 and 2004, less than 15% of NSF survey respondents described themselves as well-informed about new scientific discoveries and the use of new inventions and technologies; a sizeable minority, approximately 30% to 35%, thought that they were poorly informed .One direct measure of the accuracy of scientific literacy is to measure what the public knows about science and whether they understand the scientific process. According to one science journalist: "Without a grasp of scientific ways of thinking, the average person cannot tell the difference between science based on real data and something that resembles science at least in their eyes—but is based on uncontrolled experiments, anecdotal evidence, and passionate assertions. What makes science special is that evidence has to meet certain standards [32]". According to surveys by NSF and Pew "The public's level of factual knowledge about science has not changed much over the past two decades." Surveys reveal the public achieves between 63% and 65% correct answers on a 9-question science knowledge exam. Surveys have found that the majority of Americans (approximately 70%) lack a clear understanding of the scientific process. Although in 2001 more than 50% of the survey respondents had some understanding of probability, and more than 40% were familiar with how an experiment is conducted, only one-third could sufficiently explain what it means to study something scientifically and this pattern is consistent over time. In 2012, a minority (34%) answered the experiment questions correctly, including the questions on the use of control groups. A majority (67%) answered the four probability questions correctly. By 2012 the American public's general understanding of science had improved, with 64% of Americans understanding probability, 46% being familiar with how an experiment was conducted; but the proportion who could explain scientific study had dropped to 23% [10]. By 2012, there was little change in the understanding of probability by Americans which 65% correctly understood; although still only 34% understood an experiment and 20% understood what it meant to study something scientifically. Thus overall the public's understanding of science process was, and remains, relatively low. Indeed, "Overall, when these questions are combined into 'an overall measure of understanding of scientific inquiry,' the 2012 results are relatively low compared with those from other years" [10].

Even more significant for the purpose of this paper is the finding that the public understanding of science varies by gender, age, income and education: "With few exceptions, the NSF survey data show a strong, positive relationship between education (both level of formal education and number of math and science courses completed) and feeling well-informed about public policy issues. This is particularly true for four of the five science-related issues in the survey [7]". This problem intensifies when we consider level of understanding. Only 3% of those with a high-school education could explain a scientific study, whereas 51% of those with a graduate or professional education could explain it. Similarly whereas 39% of those in the top quartile for family income could explain an experiment, only 11% of those in the bottom quartile for family income could explain an experiment. There are also different kinds of scientific knowledge that are related to how these subsections of the American public relates to others in society.

Kinds of Public Knowledge about Science

It is important not only to know the general public's interest and depth of knowledge of science but also the kind of knowledge or what Nisbet calls kinds of scientific literacy. Nisbet identifies five kinds of "scientific literacy" relating to the public knowledge/understanding about science [20]. **"Practical scientific literacy** refers to knowledge that can be applied to solving common everyday personal problems. **Civic science literacy** means a level of understanding of scientific terms and constructs sufficient to make sense of a news report, and/or to interpret competing arguments on a complex policy matter and understanding how scientific investigation works, recognizing science as theory building, and science as a systematic testing of propositions. **Institutional science literacy** focuses on the politics of science citizens should also understand that scientists are party to many social influences, including competition, biases, errors, and career advancement. **Low information rationality** questions both the ability and the motivation of the public to be knowledgeable about science. . . Instead, the public makes up for a lack of information by relying heavily on relevant value predispositions such as religion and ideology. **A social context emphasis** highlights the contingent influence of social identity and trust on how information about science is used by the public the way a particular social group is likely to use scientific knowledge varies by how that group interprets the motivations of scientists and their institutions" [20]. Scientific communication, therefore, needs to take account, not only of the level of civic science literacy, but also the interrelations of politics, religion, ideology, social organization and social identity and the ways these affect the process of understanding science [33]. If all the focus of improved understanding of science remains on civic science literacy to the exclusion of the other dimensions, it seems that the ethical basis, and even the objectives of scientific communication, may not be met, or at least be undermined by the other social and political processes at play. Important among this cluster of processes is the public image/social identity of scientists.

The Public Image(s) and Social Identity of Scientists

According to the 2001 NSF survey, the majority of Americans believe that scientists "lead rewarding professional and personal lives, although a stereotypical image of these professions, deeply rooted in popular culture, exists and has been difficult to dislodge [31]. For example, 25% of those surveyed thought that scientists were "apt to be odd and peculiar people," and 29% thought that scientists have few other interests but their work [31].It is also generally accepted that scientists have an image problem (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development). Although both their intelligence and work are highly valued, "The charming and charismatic scientist is not an image that populates popular culture [34].

The public image and social identity of scientists is important for at least two reasons: "Scientists represent the first line of communication about science to the general public. That is, they are responsible for conveying information, often through the news media, about scientific issues. They can also help the public understand the importance of science and appreciate its benefits. Image has a lot to do with how effective that communication is in capturing the attention of the public. The more appealing the image, the more likely that people will listen to what is being said. "Children are strongly influenced by the images they see around them at home, at school, and in popular culture. Researchers in this field point out that television has a tremendous influence on children's attitudes and behaviors, and what they see on television can affect the choices they make in life, including the careers they choose. If they harbor negative stereotypes of scientists and engineers as nerdy and weird-looking, then they could reject science and engineering as potential careers" [31].

So, public interest in science, levels and types of scientific literacy, and who is communicating science for whatever motives, are important considerations in assessing the ethical basis for the process of enhancing scientific literacy. Also important are the public who are subject to scientific knowledge and its consequences. We've seen that there are differing levels of knowledge and ability and that these are subject to the distribution of class, race and gender, among other major segments of society. However, other factors also shape subsets and even subcultures of populations framing the reality of scientific literacy.

Who are "the Public" Audience for Science and Technology Issues?

So far we have been referring to "the public," meaning all non-scientific members of society. Just as there are different kinds of scientific knowledge so too are there different kinds of public who have different levels of interest in, and different involvement with and/or use for scientific knowledge. The public is far from monolithic in how it is likely to acquire and apply knowledge about science. It is important to segment the "general public" by relevant social identities and values such as religion, partisanship, education, identity, ethnicity, occupation, region, locality, and prior knowledge. This is where dialogue and interaction with the public plays a key role, as scientists and their institutions learn about the perspectives and concerns of these particular social groups, and then tailor their public understanding of science activities accordingly" [20].

It is clearly imperative to identify the audience for issues regarding science and technology so that the attitudes of these various groups can be compared and placed in the context of society as a whole. Therefore, it might be useful to classify the public into three groups, as suggested by the NSF study:

- The attentive public consists of those who (1) express a high level of interest in a particular issue; (2) feel very well informed about the issue; and (3) read a newspaper on a daily basis, read a weekly or monthly news magazine, or read a magazine relevant to the issue.
- The interested public consists of those who claim to have a high level of interest in a particular issue but do not feel very well informed about it.
- The residual public consists of those who are neither interested in nor feel very well informed about a particular issue [31].

People likely to be attentive to scientific and technological issues were identified by the National Science Foundation as those combining the attentive public for new scientific discoveries with the attentive public for new inventions and technologies. In 2001, 10% of the population met the criteria, down from 14% in 1997. In 2001, 48% of the population could be classified as the interested public for issues regarding science and technology; the residual public constituted 42% of the total [31].

It is also important to recognize that membership in any of these categories is dynamic, sociologically shaped and may depend on the topic. While some people are interested in all aspects of science and technology, many are only interested in particular areas of knowledge such as health knowledge, or subsets of health knowledge related to particular problems they have, environmental knowledge, or issues related to their local communities. It seems then that scientific communications need to be tailored for the particular population targeted, which in turn requires knowledge of that population's sub-cultural characteristics, social class position in a stratified society and access to scientific knowledge.

How Does the Public Obtain/Knowledge and Understanding and Engage with Science?

What are the best ways to improve civic scientific literacy that are both attentive to ethical considerations and are not undermined by concurrent social processes? Moreover, what are the ethical grounds justifying investment in scientific literacy? It is clear that there are a variety of forums for scientific communication around this issue, some of which stem from comments by its critics.

Alongside the long-standing public and amateur activity in science there are now events, from festivals to consensus conferences, set up with the explicit aim of furthering the public understanding of science. While much of this originates with the scientific community, and is not coy about aiming for the public appreciation of science, some activity arises from public groups or individuals who are dissatisfied with science [13].

The historically dominant view from the science community is that it is "possible to achieve a society-wide level of science literacy that would ensure public competence. In this matter, elites need only focus programmatically, on public communication efforts to increase public knowledge and appreciation.The popular science movement that flourished in the years after World War II was primarily directed at "subtle persuasion through the dissemination of uncritical information about the technical discoveries and wonders of science. These efforts were "carefully engineered to improve the public's appreciation of science as a body of knowledge and as an institution, ignoring information that might enhance the public's understanding of science in social and political context [35]".

This t op-down s ocial e ngineering m odel f or c reating a ssent f or science and technology has, in recent years, been replaced by one that emphasizes public participation, and assent. As opposed to the public being a passive recipient of scientific knowledge, the more progressive view is "public engagement with science and technology . . . implies instead a conversation about science between scientists and the public, where both sides learn about the other's perspective [20]". Thus, knowing about science becomes part of the socio-political process of citizenship and involves the process known as "deliberative democracy [36]".

Indeed, a large and growing group of scholars, foundations, and public intellectuals agree with Page that "Public deliberation is essential to democracy [37]". Public deliberation is the "process through which deliberative democracy occurs"[38]. Lindeman defines deliberation as "a cognitive process in which individuals form, alter, or reinforce their opinions as they weigh evidence and arguments from various points of view [39]", whereas for Gunderson "Democratic deliberation occurs anytime a citizen either actively justifies her views (even to herself) or defends them against a challenge (even from herself)" [39-40].

For Mendelberg, "deliberation is expected to lead to empathy with the other and a broadened sense of people's own interests through an egalitarian, open-minded and reciprocal process of reasoned argumentation. Following from this result are other benefits: citizens are more enlightened about their own and others' needs and experiences, can better resolve deep conflict, are more engaged in politics, place their faith in the basic tenets of democracy, perceive their political system as legitimate, and lead a healthier civic life[41]." The transformative effects of authentic deliberative engagement about knowledge transmission are significant. Indeed, Chambers notes that a "central tenet of all deliberative theory is that deliberation can change minds and transform opinions…. Although few adhere to the view that deliberation inevitably leads to consensus, many believe that deliberation under the right conditions will have a tendency to broaden perspectives, promote toleration and understanding between groups, and generally encourage a public-spirited attitude…. There is a widespread belief that deliberation and publicity associated with deliberation will have a salutary effect on people's opinions" [42]. A benefit of deliberation is that collective decisions can be "superior to individual ones because more information can be brought to bear [38]".Greater discussion can also increase the use of new, less commonly shared, information [43] and in the process can improve the quality of the decisions reached by the group [44]. Science communication in the deliberative engaged model involves a process of generating new, mutually acceptable knowledge, attitudes and practices. It is a dynamic exchange, as disparate groups find a way of sharing a single message [19]. Given that a deliberative model of communication incorporates an awareness of knowledge transformation, how does this translate into scientific policy making?

Scientific Literacy and Public Policy

As stated above, whether improved scientific literacy makes a difference to science policy depends on how different forms of knowledge are incorporated into the policy making process. In her work on the ways public health policy is changed Bryant argues that there has been a neglect of the political process that affects how different forms of knowledge are accepted or rejected in the health policy formation process [21]. She argues that the kind of policy a government makes is affected by its own ideological influences, but is also affected by the identity of its policy advocates. While political science contains a range of models for policy change, Bryant says that most valuable are those such as Sabatier [46] that consider the knowledge activities of competing coalitions of private and public elite groups and organizations who lobby for change. Bryant identifies health knowledge developed by experts, community members and politically engaged groups. She also identifies two main groups. Professional policy analysts who are those, typically with graduate education, who work toward health policy changes, including university professors, government epidemiologists and experts from government and nonprofit health policy agencies.

A second group of citizen activists comprises of all those outside of the expert health policy community who are advocating for policy change. Drawing on Habermas's [47] theory of knowledge, Bryant argues that groups produce different kinds of knowledge about science and health issues, do it in different ways and are received differently by policy makers. Professional policy analysts are seen producing objective instrumental knowledge developed through the application of the scientific process, regardless of whether that is a partial picture of what they do. In contrast, citizen activists develop interactive or lay knowledge about science and health, which is shared among communities related to things that affect them personally, based on lived experience.

Bryant also identifies a third kind knowledge of scientific or health issues referred to as "critical knowledge" that can come from either of these groups but may also involve independent observers of science and health issues. Critical knowledge considers the ethics of powerful socioeconomic forces that affect society, and how they reinforce inequalities in health and illness: "Critical knowledge considers questions of right and wrong, analyses existing social conditions, and outlines what can be done to alter social conditions to improve quality of life [21]". Critical knowledge can be produced by forums and meetings devoted to consider the ethics of science and may draw from both the expert and the citizen community bringing them together in a collaborative discussion of the issues that increases the scientific literacy of the citizens and educates policy experts about the social and political contexts of their knowledge: "Collaboration occurs when professional policy analysts and citizens carry out cooperative analyses on community-identified issues [21]".

In the process of science and health policy making Bryant identifies four ways these different kinds of knowledge can be presented to policy makers, and also shows how different forms of knowledge are filtered by governments. These include (1) legal presentation, (2) public relations presentations that target specific audiences about how the policy will affect their members which may involve extensive use of the media, (3) personal anecdotal stories from individuals about science and health issues affecting them and their families, and (4) political strategic presentations that target members of key committees via the use of lobbyists or others with influence. Bryant says depending upon the ideological identity of a government these various presentations will be filtered to select from some groups rather than others. Perhaps surprisingly, Bryant's research found that anecdotal and "qualitative studies were more persuasive in influencing policy makers than instrumental knowledge," and that both professional policy analysts and citizens groups used anecdotal evidence [21]. However the socio-political identity of the actors who lobby policy makers was also important in determining who got access to policy makers and what kinds of knowledge was acceptable. "Identity determined what constituted valid knowledge and evidence for government in its policy process." She further argues that while "different types of knowledge are essential to building a case to achieve particular policy change outcomes," and that "the political ideology of the government of the day and the political identity of the constituency influence the receptivity of government toward civil society actors and the ability of the actors to influence the policy change process. . . in the end, the government was willing only to heed knowledge and evidence that supported its ideological perspective" [21].

Summary and Conclusion

The forgoing review of topics related to the ethics of civic scientific literacy calls for a particular approach to scientific communication that emphasizes certain core features:

1. Identification of sub-populations of interested and aware publics; in some sense this is a marketing strategy for bringing scientific literacy to its consumers.

2. Knowledge of the issues that those public's value and are concerned about.

3. An explicit statement of the full panoply of reasons why the scientists are making the scientific communication.

4. An awareness and discussion of the political, social, ideological and moral/religious context in which the science/technology is being framed, with an open and realistic assessment of potential harms and realistic benefits.

5. An authentic participative/deliberative participatory discussion format that encourages a partnership of engagement between each of the constituent public groups and the scientific community.

In order to achieve the transparency necessary for a sociologically informed ethics of science communications it is necessary to understand the social and political contexts of knowledge production and communication, the ways these shape the different public's awareness, the way to maximize empowerment through scientific literacy and the ways this socio-politically produced scientific knowledge is differentially engaged in the science and technology policy making process. In order to ethically ground the totality of the production, communication and application of scientific knowledge we need transdisciplinary publics rather than merely scientifically literate, publics. This calls for the inclusion of all levels of knowledge and all practices of knowledge production as part of the deliberative dialog, such that science literacy is not simply a means to legitimate scientific research and application, but is constitutive of a more complete understanding of science in society.

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