Knowledges in Publics

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Edited by

Lorraine Locke and Simon Locke

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INTRODUCTION

LORRAINE LOCKE AND SIMON LOCKE

This book grew out of a Science and the Public Conference that has become an annual event in the UK over the past several years. The 6th Annual Conference in 2011 was held at Kingston University in South-West London and billed as "A Quarter-Century of PUS" to mark, if somewhat belatedly, the 25th anniversary of the publication of the Royal Society's 1985 report into the public understanding of science (PUS) (aka the Bodmer report). Against this background, the Conference was seen as an opportunity to reflect on the development of the field over its brief life-time and consider its prospects for the future. The present book continues this intent by aiming to contribute to the movement of scholarly work beyond matters of deficit, engagement and transfer principally through a strong focus on what might be called "informal science education" (see Lewenstein's chapter below).

Much of the debate about PUS concerns the relationship between knowledge, education and democracy voicing a longstanding concern in western societies over the extent to which effective citizenship requires appropriate education. Can people be proper citizens if they have not been taught how to be so? On the other hand, is educating people in how to be proper citizens merely a guise for ensuring they continue to support the status quo? What, and whose, notion of "proper" is being advocated? Similarly, by "education" do we mean only that provided by formally designated educational institutions? Or is it possible for people to become self-educated "informally", outside of such formal contexts?

The tension over whether people need "proper" direction or if they are capable of directing their learning for themselves is apparent in the debate over PUS that ensued after the publication of the Bodmer report in the UK. Bodmer's clear view was that the public needed direction. Despite evidence of strong public interest in science and a distinct absence of evidence of widespread public ignorance, Bodmer emphasised a view of the public as needing "improvement" in their understanding of science and in so doing established the basis of what soon came to be called the "deficit model" of PUS. For Bodmer, this was not just a deficit of knowledge, but also one of democratic capability; because of the extensive presence of science in more and more areas relevant to public policy, having knowledge of science and its procedures was presented as being increasingly vital to effective citizenship. If people do not understand the science (and technology) about which policy decisions are being made, then how can they be trusted to make the right decisions, both indirectly via the ballot-box and more directly via the marketplace (a point addressed in Toumey *et al.*'s chapter below). Thus, to be proper citizens they need educating in science, but it has to be science of the proper kind. The anxiety expressed by Bodmer was that, if left to their own devices, the public are not merely effectively disenfranchised by their ignorance, but even worse, vulnerable to various kinds of *improper* "science", in fact not really "science" at all, but "pseudo-science" spouted by various kinds of charlatan in a growing threat from a New Age of superstition and anti-enlightenment–an "anti-scientific" attack on the very foundation of modernity (Holton 1992).

The deficit model quickly came under strong attack, partly for its over-simplification of a complex social world made up of multiple scien*ces* with multiple understan*dings* by multiple pub*lics* (Birke 1990; Ziman 1991) and partly because it was seen as a guise for advocating continuing support for the formal institutional apparatus of science: by "understanding" was really meant "appreciation" and "acceptance" (Wynne 1992). Likewise, the notion of "anti-science" was seen as a means of deflecting and undermining public criticism of the deficiencies of this formal apparatus. From this view, the deficit resided not so much with the public as with scientists, who themselves failed to appreciate ordinary people's knowledge or accept the legitimacy of their concerns about science and technology, thereby appearing arrogant and dismissive. Thus, it is not so much the public who need to be educated in science, as scientists who need to be educated about the public and, likewise, the democratic deficit resides in the institutional apparatus of formal science. From this viewpoint, the public do not require direction by scientists, or at least not by scientist-advocates of the formal order; rather, the public are both capable of self-direction in educating themselves about science and equally capable of deciding when such education is necessary for them–and indeed, when it is not (Michael 1996).

The upshot of this debate in the UK was a shift in language from "deficit" to "dialogue" (House of Lords 2000). In practice, however, the prevailing voice in science-public relations has become that of "engagement", but the extent to which this marks a genuine shift beyond the monologue of the deficit model has been called into question (Lock

2011). On the face of it, people's participation in discussion of the activities and still less the institutional orders of formal science seems rather less sought after than their enjoyment of interactive sideshows. Accordingly, the issue of democratic deficit has again been a focus of critical attack (Wynne 2008). From this perspective, "engagement" is an avoidance tactic: a way of appearing to address concerns over public involvement in science, while actually not changing anything fundamental at all. Indeed, engagement is really "deficit" by another name, since the directing concern remains that of improving public understanding (read: acceptance) of science albeit that the strategies employed to do so are along the lines of "edutainment" rather more than the formal didacticism of the professorial voice. Not so much "citizen science" (Irwin 1995) then, as consumer science.

Alongside this sop to citizenship has come a further development at in the form of the notion of "knowledge transfer" (KT). This term, rooted in organisation and management theory, pre-dates the broad adoption of "engagement" (one of us first encountered it as an Economic and Social Research Council PUS Fellow in 1998), but has since been taken up in the UK especially in regard to university research, which is now to be assessed for its KT "impact". This seems to cover a range of possible relations with wider publics, although perhaps with a preference for economic actors since KT is linked to notions of the "knowledge economy", thus emphasising the role of knowledge in directing innovation and production. In this respect, "transfer" is at the other end of the economic chain to "engagement" and taken together they might be seen as partners in a dual strategy to direct economic action principally through science-driven technological innovation. It is, after all, one thing to look to science as a source of new products, but quite another to ensure there is a ready supply of eager consumers for those products. If and in so far as developed economies now do look to science as the basic engine-driver of economic growth, then its legitimacy needs to be upheld or the products themselves may be seen as part of the problem rather than the solution. Thus, encouraging citizens to participate in genuine debate about the formal institutions of science is potentially perilous, since they may call into question the steering of scientific research toward currently preferred agendas of technoscientifically-constituted economic activity.

Viewed in this light, KT arguably shares with "engagement" the same basic framework of deficiency. Although there is much emphasis on recognising the grounding of knowledge in local "networks", nonetheless, the metaphor of "transferring" conveys the sense of shifting a given thing from one context to another in an essentially unchanged form.

Accordingly, knowledge is apparently invested with a thing-like quality, as something that can be simply reproduced from one situation to another, as in, for example, notions of transferring "best practice", carrying the implication that practices are divorceable from the immediate social contexts in which they are constituted and that they constitute. Such a conception of knowledge as a clearly bounded, thing-like given that can be lifted from one context and placed into another without change, informs the "knowledge-quiz" surveys that arose from the deficit model and came to epitomise its major flaws (Evans and Durant 1989; Irwin and Wynne 1996). KT indicates that, at least amongst those responsible for governing publicly-funded scientific research, there is little real interest in encouraging genuine public dialogue and rather more in imposing a restrictive regime of knowledge production in the hope of revivifying a flagging economy, the barbaric (in Matthew Arnold's sense) assault of the current UK coalition government on the social sciences and humanities being perhaps a more obvious indicator.

The papers in this book, however, point in varying ways and to different degrees to a significantly different conception of knowledge and its public(s). As stated, broadly these studies fall into what, following Lewenstein, we will call "informal science education", incorporated into which, as he outlines, are such outlets as museums, theatre, the mass media and fiction involving science. Accordingly, we have divided the papers into three parts reflecting their concern with: knowledges in publics; public venues of knowledge (museums and theatre); and public mediations of knowledge (mass media and popular culture).

Part One: Knowledges in Publics

The two papers in Part One provide summary overviews of the general state of discussion at the present time regarding how best to conceptualise the relationship between the public and science. Although both document discussions held in the United States, the issues they address have some general applicability, as indicated by the reference they make to the Bodmer report, but also as becomes apparent from ensuing chapters in which aspects of the global reach of the science-public relation are documented and explored.

As Chris Toumey *et al.* make apparent, these matters are of longstanding interest in the United States, which has had a tradition of survey research into "science literacy" reaching back over several decades. However, while acknowledging the longitudinal value of this work, their remit arose from recognition by the National Science Board of the

National Science Foundation that there was a need to revise the existing approach, which narrowly construed “science literacy” in terms not unlike those of the UK and European deficit model. Even by its own criteria of democratic efficacy, Toumey *et al*. consider this approach flawed, partly because it is not clear that high levels of science literacy are either attainable or necessary for effective democratic action and partly because the politically motivated conception of why people may want scientific knowledge is too circumscribed. Instead, Toumey *et al.* propose a framework for assessing public knowledge of science that adds two further interests to this “civic” motivation: “practical individual decision-making”; and “cultural curiosity” about science. In addition, they suggest that what is meant by “scientific knowledge” can cover three broad types of content: “scientific facts”; “processes and standards”; and “scientific institutions”. Combining these produces a three by three framework of “purposes and content” from which to begin to develop a more sophisticated assessment of public knowledge of science conceived in the general manner of “science in the service of citizens and consumers” (consumers, that is, of knowledge).

Despite misgivings in some quarters as Toumey *et al.* record, the framework has been welcomed by the British Science Association and promises to make a significant advance over existing survey-based approaches, so we are very pleased to be able to present it here for wider European audiences. As the team also acknowledge, however, it remains restricted to assessing scientific “knowledge” and not “interpretations” of this knowledge, a distinction that is not necessarily clear-cut as some of our later chapters show. Nonetheless, one of the strengths of the framework is that it attempts to recognise the multiplicity of the public’s relationship to science and the diversity of sources of knowledge that self-directed learners may employ. Moreover, in incorporating some measure of “institutional knowledge”, additional recognition is given to the social context within which scientific knowledge is generated and applied. In these respects, there is strong continuity with Bruce Lewenstein’s following chapter on “informal science education” (not altogether surprising, given his involvement with both reviews).

Lewenstein summarises a report on *Learning science in informal environments* commissioned by the National Research Council of the United States National Academy of Sciences, but also uses this as an opportunity to reflect a little on what he suggests can be considered a “[natural] scientific” approach to PUS. The reason for this is because the report was subject to peer review, which brought out issues over different standards of evidence employed by natural scientists vis-à-vis social scientists and humanities scholars; as Lewenstein neatly sums it: "'data' is not the plural of 'anecdote'." Consequently, much of the case study research found in science and technology studies–the sort of research, in fact, that makes up the bulk of this book–might be deemed of insufficient validity by the NRC, however persuasive social scholars of science may find it. Given that, from Lewenstein's account, this includes much of the work on informal science learning (i.e., the sort of learning that occurs in contexts outside of formal education and related institutions), it can perhaps more readily be appreciated that natural scientists may be unwilling to count such learning as really "science". On the other hand, we might also turn this around and view the resort to such methodological matters as a standard technique of boundary-work (Gieryn 1999), long recognised in science studies as an exclusionary tactic (Collins and Pinch 1979). Thus, in pointing out this issue, Lewenstein makes us aware that such defensive manoeuvres are available for deployment even in what he calls a "backstage" arena. Nonetheless, he ends on a hopeful note, concluding that it is important to sustain the conversation across the disciplinary boundaries and that the field of science and the public has great significance as a meeting place.

Lewenstein highlights a number of features of the report itself, which identifies a range of "venues" of informal learning (such as museums) and "themes" that inform such venues (such as media), as well as offering a way of thinking about "learning" as a weaving together of six "strands" that are not restricted to formal educational contexts. Amongst these, he points especially to reflection on scientific institutions as a significant inclusion for the involvement of science and technology studies, using as an illustrative example the case of museums as both major cultural institutions and venues where "personal interaction" between visitors and staff can occur. These features significantly figure in the two chapters that follow.

Part Two: Public Venues of Knowledge

In Parts Two and Three of the book, we move from general theoretical and conceptual discussions to specific examples of empirical research. Part Two includes studies of two major kinds of venue in which informal science is displayed and performed: museums and theatre.

In chapter three, Claudia Geyer, Katrin Neubauer and Doris Lewalter report on their evaluation survey of visitors to a number of museums across Europe involved in the EU Commission funded NANOTOTOUCH project. The project aims to make the scientific laboratory directly accessible to the public by setting up nano-research facilities within museums and encouraging visitors to interact with the researchers. Geyer *et al.* focus on assessing the effectiveness of the project in terms of how well it succeeded in generating and sustaining visitors' "situational interest" in nanotechnology and their self-perceived increase in knowledge about nanotechnology and research. Amongst the key findings is that the perceived relationship to the scientist is closely related to both these factors: the better the perceived relationship, the better the reported experience and learning. This supports Lewenstein's point that museums are particularly well-positioned to take advantage of the personal interaction with staff scientists their venues afford.

The other feature of museums Lewenstein picks out is their significance, not merely as venues for "knowledge transfer" narrowly defined, but also as national and cultural heritage sites with the potential to locate science and technology in wider social contexts. This is developed in chapter four, Ines Hülsmann and Ana-Maria Raus's study of displays of the pacemaker. Drawing on actor-network theory and so providing a qualitative counterpart to Geyer *et al.*'s quantitative analysis, Hülsmann and Raus describe how pacemaker technology is represented in three different Dutch venues, a museum, a science centre, and a manufacturing company. Their descriptions clearly show how ostensibly the same "object" is quite differently configured in these different sites demonstrating that there is no simple "transfer" of knowledge, but a distinct "translation", which in each case offers quite different relations to visiting publics. This is made all the more apparent by the fact that the science centre works directly with the manufacturing company and yet displays the technology in a significantly different way, to the point that one company interviewee expresses concern that the centre provides not "edutainment" but merely "entertainment" (evidently then, it is not just social scientists who worry about the "engagement" agenda, even if for rather different reasons). In a notable point of confluence with Geyer *et al.*, Hülsmann and Raus also highlight the importance of the interaction between venue staff and visitors, and they echo Lewenstein in proposing that all the venues could do more to increase awareness of the social in science and technology.

One venue where such awareness is being articulated, at least to some degree, is theatre and our next two chapters provide examples of two rather different approaches to accomplishing this, which despite contrasting starting points, show significant convergence towards similar outcomes. In chapter five, Jeff Teare provides a summary overview of the work to date of Theatrescience, a drama company that has become increasingly involved in developing and exploring ways of using drama to address moral and ethical issues involving science. From the outset, Theatrescience's work involved more than simply putting on plays; rather, with the support of bodies such as The Wellcome Trust and the Eden Project in the UK, they have explored ways in which to bring together drama writers and practitioners with scientists and publics in schools, at science centres and in wider communities. As part of this, they have sought to break down longstanding barriers between the arts and science and, in this respect, provide a practical example of the kind of interdisciplinary conversation afforded by the field of PUS. They have also worked internationally, notably in India and Africa, on developing dramatisations of health and related issues that involve direct input from affected communities and it is here especially that their work shows convergence with that of Aiding Dramatic Change in Development (ADCID).

In chapter six, Stephen Sillett and Jennifer Jiminez provide an account of ADCID's work involving Socio-Drama Topography (SDT). This is described as a "reflective and dialogical arts-based inquiry process" that seeks to use dramatic techniques developed with the active involvement of communities to air local issues with a view to encouraging reflection and greater empowerment for participants. The two applications of SDT outlined in the chapter are concerned with health and environmental issues in deprived areas of rural South Africa in which western scientific understandings are crucially positioned. In the first case concerning HIV/AIDS, from which the SDT approach was first developed, the project was concerned with improving young people's adoption of safe-sex practices and involved learning from both the youth and their parents about traditional views of sexual relationships and their importance to identity. Drama was then used to facilitate community discussion and reflection with a view to developing knowledge and changing practices towards "healthy choices". In the second case, focused on issues of water access and hygiene, SDT was employed from the outset to assist a community-based organisation seeking to change from a more technically-driven mode of service provision towards greater community partnership. As Sillett and Jiminez put it, this "involved a shift in engagement from transferring knowledge and servicing needs to developing the 'power to empower'." In short, a shift from top-down to bottom-up and from formal, institutionally-directed knowledge to informal, locally-grounded knowledge.

Thus, despite their rather different starting points, both Theatrescience and SDT have developed forms of drama-based intervention that attempt to encourage participatory involvement of local communities and to incorporate their knowledge(s) into the learning activity. There is about this a clear resonance with established critiques of the deficit model that also emphasise the importance of local knowledge(s), a matter that arises again, albeit in rather different fashion, in Part Three.

Part Three: Public Mediations of Knowledge

In Part Three, we shift locus from what might once have been considered “high culture” venues to the mass media and popular culture, beginning with two chapters looking at science and scientists in newspapers and magazines.

In chapter seven, Miquel Carandell provides a detailed analysis of the fascinating controversy in the Spanish press over a fossil bone fragment referred to as “Orce Man”, with respect to its classification as indeed a hominid or merely a donkey. The matter was controversial, because its acceptance as hominid presented a challenge to the prevailing view of when early humans arrived in Europe. Carandell uses the case to assess the applicability of a number of models of science popularisation and to highlight that newspapers may themselves become a site for establishing scientific knowledge (referred to as “medialisation”). In this way, the traditional sharp division between formal contexts of scientific knowledge production and the informal context of popularisation is called into question, as it is argued that for at least some members of the scientific community, newspaper reports provided the primary source of information regarding the nature and status of the fossil. Further, not all the scientists involved were distant from the controversy, but some closely involved. The case then provides reinforcement for the view that learning about science is something that can occur in a range of contexts, whether considered “formal” or “informal” and that this is not just true for non-scientists. Members of the scientific community may also rely on “informal” sources, troubling the distinction between scientists and the public and raising a question about how we should view these categories themselves.

One proposal in response to this question comes from Simon Locke in chapter eight, in the form of a preliminary application of Membership Categorisation Analysis (MCA) to some treatments of academics and doctors in newspapers and magazines. MCA is a perspective associated with Harvey Sacks (better known for having founded conversation analysis), which over recent years has become increasingly widely used to study the ways in which categories are employed by people in everyday life to make sense of their own and others’ activities. Actions can be matched to categories and categories to actions providing us with a ready interpretative apparatus to understand what is going on in a given situation. Arguing that category usage involves rhetorical reasoning conforming to the incomplete syllogism of the enthymeme, Locke provides illustration of how non-scientists writing in the mass media can use the attributes or "predicates" associated with the categories "academic" and "doctor" to construct critical accounts of science and scientists. In particular, he notes that academics may be judged "bad" in relation to a set of norms of a broadly Mertonian form that are often found in popularised representations of scientists. Thus, scientists are held publicly accountable to a moral order they have themselves worked to constitute in public. Similarly, from consideration of contemporary press reports of Jack the Ripper, Locke suggests that members of the public may draw on scientific knowledge to construct versions of "madness" to which scientists are then held accountable, even as actions attributed to the category of "scientist" are judged by the existing moral order, in particular acting instrumentally. Finally, Locke also gives some brief consideration to the additional category "local" to point out that the use of this common sense construct by social scientists as a resource with which to criticise the deficit model demonstrates our own reliance on ordinary social-rhetorical reasoning, further troubling any easy distinctions between scientists (natural or social) and the public, and between formal and informal knowledge.

Such questions arise also in relation to fiction involving science in which, in a variety of ways, the boundary between "fact" and "fiction" becomes distinctly (and oxymoronically) fuzzy and our last two chapters carry this matter forward in two novel (pun intended!) directions. In chapter nine, Alice Bell looks at the classic British children's character, Professor Branestawm, as an example of how images of the scientist may be informed by (modern western) cultural representations of the child. Bell points out that there are a variety of contrasting qualities associated with children, such as being innocent or corrupt, that may also be associated with scientists and enable positive or negative images of the latter to be constructed through the former. In the case of Branestawm, she suggests that a range of positive qualities of the child are combined with "anti-childlike", "mature" features that enable different versions of the character to be presented, which she tracks over the course of his 50 year history (from 1931-1983). She further suggests, however, that such negotiations of the "child/scientist boundary" are not just to be found in the fictional character, but also amongst "real world" scientists, "to take advantage of both positive qualities of childishness as well as the advantages of appearing distinctly 'mature'." Thus, through studying such fictional characters, we may learn not only much about the common sense attributions associated with scientists, but also perhaps, those with which scientists may seek to associate themselves. This then is one way in which the "informal" context of popular fiction may blur over into more "formal" scientific self-representations.

Bell's discussion points to the "ambivalence" with which scientists are represented in children's literature, a matter that comes through also in our final chapter. Here, Kate Roach raises the intriguing question as to why the "scientific detective" has been largely excluded from discussions of fictional representations of the scientist, which tend to focus over-narrowly on "mad" scientist figures, themselves often viewed as one-dimensional critiques of the "evils" of science. Through detailed consideration of some of the most influential early detectives in 19th century popular fiction, she argues they were represented as "men of science", but also incorporated "occult" qualities that, during the 20th century, became marginalised from formal science. Yet, in popular culture, such figures retain an important presence, most prominently in Dracula's nemesis, Professor Van Helsing, both scientist and supernaturalist. Together with the more widely studied (in the PUS literature) mad scientist proto-type, Doctor Frankenstein, Van Helsing makes up something of a double-act that looms large over contemporary popular images of the scientist and from which a host of fictional progeny has spawned. Roach suggests that this supports the view that the public meaning of science remains mixed and uncertain, combining both enchanted and disenchanted qualities that are played out and explored through such images. Popular culture, then, is a site where the meaning of science is debated in part through such narratological resources and the implications of this for both "formal" and "informal" science education are much in need of further study.

Taken overall, this is the message of the book: that the need remains to move the agenda of PUS beyond matters of deficit, engagement and transfer, all of which despite the differences in their packaging prioritise the position of formal institutional science as the primary source of knowledge production in our society. Our commitment, in contrast, is to a view of knowledge as something that pervades all parts of the social world, as a stock of sedimented typifications, discursive practices and artful accomplishments that underwrite and make possible all forms of social life including those we call the sciences. In the first instance, science grows from the everyday lifeworld (for which the term "public" is a certain kind of synonym) and though, as it feeds back into it the lifeworld may become transfigured, science is itself transmogrified in the process. Such transformations, however strange and unusual they may seem and however "informal" their constitution, require empirical study and understanding more than anxious condemnation or self-interested re-direction. Publics *do* things with science, they generate their own knowledges in accord with their own concerns and criteria, regardless of the needs and desires of any formal, institutional apparatus: get used to it.

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Part One

Knowledges in Publics

CHAPTER ONE

RETHINKING PUBLIC KNOWLEDGE OF SCIENCE: THE PROCESS OF CRAFTING THE CONCEPT OF "SCIENCE IN THE SERVICE OF CITIZENS AND CONSUMERS"

CHRIS TOUMEY, JOHN BESLEY, MEG BLANCHARD, MARK B. BROWN, MICHAEL COBB, ELAINE HOWARD ECKLUND, MARGARET GLASS, THOMAS GUTERBOCK, ANTHONY E. KELLY AND BRUCE LEWENSTEIN

Introduction

The *Science and engineering indicators* (hereafter *Indicators*) is a massive compilation of data that is assembled by the staff of the United States National Science Foundation (NSF) and published biennially by the National Science Board (NSB). Chapter Seven of the *Indicators* is titled "Public attitudes and understanding". When the 2010 edition was being prepared, some members of NSB criticised the item on public knowledge of evolution: "Human beings as we know them today developed from earlier species of animals". This item, they asserted, failed to distinguish between *knowledge of* evolution and *belief in* evolution (Bhattacharjee 2010). A person could know that scientists say that humans have evolved, but still disagree with the scientists; in that case, which is sometimes detected in survey research, the interviewee knows how evolution is presented by scientists or the authors of textbooks, but at the same time he or she does not believe in evolution. In the view of some members of NSB, the wording of the item on evolution captured *belief in* evolution when it should have captured *knowledge of* evolution instead.

After a series of communications were exchanged between NSB members and NSF staff, it was agreed that the conceptual framework for public knowledge of science, as reported in Chapter Seven of the *Indicators*, ought to be reexamined. A workshop at NSF was planned to reevaluate the conceptual framework in October 2010, with a follow-up workshop to devise methods to implement the recommendations of the first in November 2010. The authors of this paper participated in the first workshop, and some members also contributed to the second workshop. Here we describe the process of: (1) examining the former conceptual framework; (2) suggesting a different framework; (3) clarifying the implications of the second framework; (4) observing how the second framework was incorporated into documents of the National Science Board; and (5) observing how the second framework was reported in science media.

The topic of public knowledge of science deserves a rich interdisciplinary approach. The participants for the workshop of October 2010 had expertise in science communication, science policy, science education, informal science education, survey design, learning-and-cognition, science-and-culture, and other related areas. That way the group could look critically at public knowledge of science from multiple relevant perspectives.[1]

From Civic Scientific Literacy to "Science in the Service of Citizens and Consumers"

Why should the National Science Foundation measure public knowledge of science, and why should the National Science Board publish this information? These were the initial questions that the workshop considered. The workshop participants noted that NSF and other governmental science agencies have a legitimate interest in knowing how the public examines scientific evidence, how the public reasons about evidence and how it uses evidence to make judgments either as individuals or as communities. In the words of NSF's (2003) strategic plan, one of its objectives is to

> promote public understanding and appreciation of science, technology, engineering, and mathematics, and build bridges between formal and informal science education.

For purposes of conceptual clarity, the workshop participants used the term “public knowledge of science” for three reasons. First, there was concern that the expression “public *understanding* of science” has acquired a highly charged negative connotation in both the research and the policy communities as a result of criticism of projects conducted earlier under that title. This problem arose after the Royal Society presented its 1985 report, *Public understanding of science*, also known as the Bodmer report (Royal Society 1985). This document has been widely diagnosed as a plan in which scientists talk, members of the public listen and then the public uncritically supports government funding of scientific research. An opposition to that plan quickly crystallised, as represented in Brian Wynne’s (1992) paper, “Public understanding of scientific research”. There, the author asserted that the Bodmer report was motivated by scientists’ selfish fear of losing public support for science. In the words of Wynne (1992, 42), this reflected “the social neurosis of science over its authority and public legitimation”, in which the work of scientists is not vetted by the public. Wynne (1992, 37) writes that “problems in public understanding of science reflect problems in the representation, organisation and control–the broad political culture–of science”. This and other critiques have painted the Royal Society report as misguided and unrealistic. We note that Sir Walter Bodmer recently defended the report, saying that critiques have oversimplified its conclusions (Bodmer 2010).

Second, the conceptual framework to be reevaluated, public knowledge of science, is often identified with the term “civic scientific literacy”. If hypothetically the workshop was to recommend a different conceptual framework, then the themes of the new framework would lead to a new terminology. Third, “understanding” can include both the scientific knowledge that the public possesses and the attitudes, values, concerns, perceptions and other factors that shape public interpretations of that knowledge.

The workshop participants were charged to reevaluate the conceptual framework for public knowledge of science, but not the influences that shape interpretations of knowledge. Those other influences are interesting and important, but the problem at hand was public knowledge of science. Furthermore, a reevaluation should think about the future: how can a conceptual framework improve the process of measuring and reporting information for the 2014 *Indicators* and beyond?

The first order of business of the workshop was to examine the history of measuring and reporting public knowledge of science. Dr Robert Bell of the Science Resources Statistics Division at NSF (subsequently renamed as the National Center for Science and Engineering Statistics) presented this history from an administrative perspective, after which the workshop participants discussed the contributions and conceptual framework of Dr Jon D. Miller, who established a framework known as civic scientific literacy (CSL) in 1983, with various revisions since then (Losh 2006).

Miller's framework was anchored in John Dewey's theory of liberal democracy, particularly Dewey's 1934 essay on "The supreme intellectual obligation" (Dewey 1981 [1934]; Miller 1983, 1987a, 2004). Here, Dewey argued that if citizens know how to think scientifically, then democracy will benefit from good knowledge combined with good decision-making processes. According to Miller's (1983, 29) account,

> In a democratic society, the level of scientific literacy in the population has important implications for science policy decisions…any measures we can take to raise this level…will improve the quality of both our science and technology and our political life.

None of the workshop participants opposed civic scientific literacy *per se*. Nevertheless, they identified two reasons to develop an updated conceptual framework. One is that the former vision has not been attained. It is possible that higher levels of scientific thinking might or might not affect democracy for the better, but there is little reason to be optimistic that the American public will achieve the levels of scientific literacy that Dewey and Miller hoped for. The civic virtue that Dewey envisioned included individuals voting and making personal decisions. Some readers might further infer that Dewey also called for the kinds of large-scale political grassroots organising that are required to support or resist a particular science policy. Even so, telephone surveys have not captured that latter possible dimension of civic scientific literacy. It can be recognised that large-scale political activism is now a common feature of public scientific controversies in creation-evolution disputes, AIDS/HIV policy, environmental issues, and other topics. That level of activism on scientific topics proceeds with or without desirable levels of scientific literacy. A conceptual framework for public knowledge of science should reflect the reality that scientific knowledge is acquired and deployed, not only in voting in elections and referendums, but also in additional styles of civic engagement.

The second reason for reevaluating the conceptual framework of civic scientific literacy is that this vision frames the person in the public as a micro-scientist. That is, it identifies some of the knowledge that working scientists possess and then measures how much of that knowledge non-scientists possess. Consistently the answer is that most of the public possesses miniscule quantities of scientific knowledge, leading to stories with titles like “America’s scientific illiterates” (Russell 1986), “The dismal state of scientific literacy” (Culliton 1989), and “The scientifically illiterate” (Miller 1987b). The workshop did not challenge the validity of these reports.

What should be the standard of acceptable civic scientific literacy? Sometimes it is said to be the ability to read the “Science” section in the Tuesday edition of the *New York Times*. Why? If a citizen accepts that scientific information passively or uncritically, is this an acceptable form of civic scientific literacy?

The workshop participants agreed that decades of data collection from surveys of civic scientific literacy have enabled high-quality longitudinal research. Long-term trends can be identified and analysed. Likewise, comparative research is made possible. Public knowledge of science in the United States can be weighed against the same in other nations and perhaps insights can be derived from that kind of comparison. This kind of analysis is already made possible for K12 science education, e.g., in the *Science framework of the 2009 national assessment of education progress* (NAGB 2009). It would be regrettable if the longitudinal and comparative value of that information was diminished.

Following that conclusion and with the benefit of the participants’ expertise in science communication, science policy, science education, informal science education, survey design, and other related topics, the workshop explored ways to improve the conceptual framework by incorporating recent thought about relations between the science and the public. One insight that was especially salient is that persons in the public have different reasons for acquiring scientific knowledge and using it (e.g., Bell *et al*. 2009; Shen 1975; Toumey 2006; Wickson *et al*. 2010).

Sometimes a person is in the role of an information consumer and so wants the kind of practical knowledge that enables one to comprehend the ingredients in a food label, or to know how to take antibiotics without developing antibiotic-resistant bacteria. Other times a person is in a civic role and needs scientific knowledge in order to have an active and constructive role in a science policy decision-making process. If a nuclear reactor is planned near one’s home, what knowledge will a person need to weigh the benefits and the risks, and then to participate in supporting or opposing the construction of the reactor? In a third situation, a person might feel that science is interesting and learning about science is enjoyable. Unlike the reasons of the consumer or the citizen, this motive has merely the pleasure of learning about science. We can call this public knowledge of science for its own sake and we can note that by acquiring it, people are connected to a shared view of how the natural world works.

In addition to considering the reasons *why* people acquire scientific knowledge, it is worth realising that there are *different kinds* of knowledge and that some kinds will serve one purpose while others serve another. The consensus of the workshop was that there are three principal categories of scientific knowledge that can serve persons in the roles of information consumers, citizens, and the curious:

1. *Factual scientific knowledge* gives one a vocabulary of scientific information and scientific conclusions about the empirical world. For example: What is an atom? What is a species? What is a vitamin? What are genetically modified organisms? What are stem cells? In addition to knowledge that might be conveyed as definitions, it also includes natural and technical processes: What is adaptation, and how does it work? How does a solar cell work? How does a nuclear power plant work?

2. *Knowledge of scientific processes and standards* enables one to comprehend intellectual practices such as experimental design, naturalistic explanation, sampling and probability, and so on.

3. *Institutional scientific knowledge* enables one to know how scientific institutions operate. This includes peer review; the adjudication of scientific claims; the funding of scientific research; how science identifies and prioritises emerging issues; how scientific advice is used; processes of making science policy; and so on.

From those considerations comes the core of a conceptual framework for measuring and reporting public knowledge of science in the *Indicators*:

> In order to place science in the service of citizens and information consumers, the concept of public knowledge of science refers to: (a) factual scientific knowledge; (b) knowledge of scientific processes and standards; and (c) knowledge of how scientific institutions operate. It equips persons in the public for: (1) active civic engagement in scientific issues, including organised efforts to support or oppose specific science policies; and for (2) using scientific knowledge for practical decision-making by individuals; and for (3) a better scientific understanding of the world.

In addition, the process of measuring and reporting public knowledge of science continues the long-term responsibility of collecting data which enables high-quality longitudinal and comparative analysis.

This conceptual framework can be envisioned as a three-by-three matrix. The horizontal dimension represents three purposes for acquiring knowledge, and the vertical dimension depicts three kinds of knowledge content. One can then categorise items to be measured according to which purpose they serve and what kind of content they represent (Table 1.1).

		Purposes of public knowledge of science		
		Civic engagement with science	**Practical/ individual decision-making**	**Cultural curiosity about the scientific worldview**
Content	**Factual knowledge**		How should antibiotic medicines be used?	What is an electron?
	Processes and standards	How is probability relevant to a particular issue?		Principle of naturalistic explanation
	Institutional knowledge	Why does nano-technology receive government funding?	Which experts and institutions can I trust?	

Table 1.1. A 3x3 matrix of Purposes and Content showing how certain kinds of knowledge fit into cells

For example, the principle of naturalistic explanation would belong in the row for scientific processes and standards and the column for scientific understanding of the world. It would also go in the column for the civic purpose of public knowledge of science in the case of a policy controversy about evolution and creationism. But it is not necessarily urgent for it to be in the column for the practical purpose of serving consumers. One can imagine how a person who wants to understand the label of ingredients on