The Vicissitudes of 'Public Understanding of Science': from 'Literacy' to 'Science in Society'

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[摘　要] "公众理解科学"一词涉及科学与社会的关系，有两个方面的含义。一方面是指有公众参与的各种各样的科普活动。其表现往往带有社会行为的特征，有主导人物、资源和不断扩大的活动储备。另一方面是指一个不断发展的经验性社会研究领域。本文重在论述后者的演变，它分为3个阶段，即科学素养（迄于20世纪80年代）、公众理解科学（20世纪80年代到90年代）和科学与社会（20世纪90年代后）。这里称谓的变化不容忽视。各阶段的陈述均包含针对科学与社会之关系的症结所做出的专门判断，特别要研究的问题以及优先考虑的介入策略；同时可以看出，各阶段之更替在修辞上表现出的是一种"进步"。比较此3个"范式"之后，作者不禁发问：此领域中的研究工作真的有什么进步吗？

[关键词]　科学素养　公众理解科学　科学与社会

Abstract: The term 'public understanding of science (PUS)' considers the relationship of science and society with a double focus. On the one hand it refers to a variety of activities that engage the public with science. This takes at times the character of a social movement, involving actors, resources, and a growing repertoire of activities. It is on the other hand a growing field of empirical social research. This paper will trace developments in the latter through three phases, which are associated with a change in language: from science literacy until the 1980s, to public understanding of science from the 1980s into the 1990s, and science and society since the 1990s. Naming matters here. Each period is associated with a particular diagnosis of the problems in the relationship between science and society, particular research questions and preferred intervention strategies, and each period displays a rhetoric of 'progress' over the previous one. Comparing the three 'paradigms', I will ask the question: is there any progress in this field of research?

Keywords: science literacy; public understanding of science; science and society

This paper attempts to map the public understanding of science research in Europe over the last quarter of a century. [1] Far from being comprehensive, it points to some achievements and lacunae, and it shows in a schematic manner how the discussion has changed during that period.

The term 'public understanding of science' is an ambiguous phrase. On the one hand it refers to a diversity of activities that aim at bringing science closer to the public, on the other it refers to research that tries to determine what the public's understanding of science may be. I will say a few words about the former, but focus mainly on the latter.

1. The social movement that promotes the 'public understanding of science'

For many people working at the boundaries between science and the public, the 'public understanding of science' became a rallying cry, a banner or flag around which to gather and to do better work. It may be illuminating to consider those who engage in bringing science closer to the people as a social movement that comprises actors, resources and a repertoire of activities.

Among the actors we find traditionally the scientists who communicate to a wider audience; these have been called the visible scientists. But there are also the professional science writers who write in newspapers, magazines, radio and television or popular science books. Then there are the staffs of science museums and science centres, the activists in societies such as the British Association for the Advancement of Science or its sister institutions in many countries. Increasingly there are the press officers of scientific laboratories, professional scientific bodies and universities who prepare news events, press releases or annual reports to create a better public profile for their institution.

All these actors draw on resources. Their funding may come from public or private sponsorship, from members, or from selling stories or expert advise on how to deal with the public. Resources are not only money, but also ideals and motives which support the notion that science and the public need to be ever closer. The ideals and the motives for public understanding of science are perennial topics of public speeches and addresses by the great and the good of learned societies. Ideals about public education compete with self-interest, public entertainment, national pride in international competition, or more managerial notions such as public relations for the purpose of creating a favourable image for science or a particular institution (e.g. Gregory & Miller, 1998; Gregory & Bauer, 2003). A public profile and favourable image is important to sustain public and private goodwill that may translate into funding for future scientific research.

The activities that are supported are exhibitions, science festivals and events, press releases, science coverage in the press, popular science books and film, radio and television programmes, public hearings, meetings and internet sights, consensus conferences, deliberative opinion polls, citizen juries etc. This repertoire of activities has grown and multiplies with every new communication technology that becomes available.

An inventory of actors, activities, resources and ideologies of the public understanding of science is urgently needed. Such attempts were undertaken by Schiele (1994) covering Europe, North America, Africa, Australia, and Japan, and a more recently for Brazil by Massarani, Moreira and Brito (2002). What is missing is a comparative data base. A team of European colleagues has presented recently impressive groundwork in that direction (Miller et al., 2002).

A feature of the public understanding of science movement are its ups and downs. We know very little about these waves of activity, but preliminary evidence over the last 150 years (e.g. Bauer, 1998) shows several periods where the popularisation of science was high on the agenda: in the years between 1870–1885, in the 1920s, again between 1955 and 1965, and more recently since the mid 1980s. The very writing of this paper surfs the latest wave. Equally, the membership of organisations such as the BA (Btitish Association) or the AAAS (American Association of Science) and similar organisations worldwide is not constant, which indicates changes in public mobilisation for science (see Kohlstedt, Sokal & Lewenstein, 1999). In between the peak times, the concern for public understanding of science fades away or presents itself in more quiet manners.

However, the periodisation of such waves of activity in public understanding of science is one thing, their explanation another. A long-term account may have to assess the functions of the public understanding of science movement that spans the boundaries between science and the public sphere. Might it be that whenever science faces a crisis of public confidence, PUS comes into focus? For example the British House of Lords has officially diagnosed a 'crisis of confidence' in society towards science (House of Lords, 2000) while PUS activities are at all historical high. Could it be that PUS contributes rather than attenuates a crisis of confidence? Be that as it may, these hypotheses need to confront the historical evidence. Undue generalisation from present observations amounts to an historian' s fallacy of anachronism. One has to await the ambitious historical account that remains a desideratum.

2. Researching the 'public understanding of science'

Over the last 20 years the public understanding of science has spawned a field of social research that engages sociology, psychology, history, communication studies, and science policy analysis. It remains somewhat marginal but vigorous in its output. The field displays a tension between two somewhat incompatible research purposes. On the one hand there are the concerns of the PUS movement to reach the public and to make communication more effective and more efficient. On the other hand there are those, who, often less engaged, are researching the public understanding of science with a view as to the unintended consequences of otherwise good intentions.

Table 1 gives a schematic overview of three 'paradigms' of research into public understanding of science. Each paradigm has its prime time, more or less precisely defined, and is characterised by a particular diagnosis of the problem that science faces in its relationship with the public. A key feature of each paradigm is the attribution of a deficit either to the public or to science itself. This leads to particular research questions, and solutions and interventions strategies to solve the problem towards a better future for science. I will briefly characterise each of them in turn.

Table 1: Different periods: different problems and solutions

Period	Attribution Diagnosis	Strategy PUS Research
Scientific Literacy 1960–80s	Public deficit: knowledge	Measurement of literacy, Education
Public Understanding 1985–90s	Public deficit: Attitudinal	know x attitude, attitude change; education; Advertisement, PR
Science & Society 1990s –	Expert deficit: Expert notions of public; Legitimacy crisis	Participation; Deliberation; 'Angel' roles; Impact evaluation;

Scientific Literacy (1960s – 1980s)

The idea of 'scientific literacy' builds on a double analogy. On the one hand it suggests that science is part of the cultural stock of knowledge everybody ought to be familiar with. Scientific education ties in with the quest for 'basic literacy' in reading, writing and numeracy. The second source of analogy is 'political literacy' . Here the idea is that in a democracy people take part in political decisions, directly in referenda or indirectly by electing their representatives or as voices of public opinion. However, this can only be effective if people command basic knowledge about the political process and its institutions. For people to have a voice, they need a familiarity with political process and its institutions. The axiomatic assumption is that scientific as well as political ignorance breeds alienation, demagogy and extremism.

The literacy idea attributes a knowledge deficit to the public, who, for whatever reasons, is ignorant or not literate enough and therefore in need of improvement. This deficit model of the public serves the education agenda demanding increased efforts in science education at all stages of the life cycle. However, it also plays into the hands of technocratic attitudes among decision makers: the public is de–facto ignorant and therefore disqualified from partaking in science policy decisions.

An influential conception of 'science literacy' was proposed by Jon D Miller in Chicago (1983 and 1992). Miller's definition included four elements: (a) knowledge of basic facts of science, (b) an understanding of scientific methods such as probability reasoning and experimental design, (c) an appreciation of the positive outcomes of science and technology for science, and (d) the rejection of superstitious beliefs such as astrology or numerology. Miller constructed survey based indicators for literacy, based on some earlier work by Withey (1959; see also the review of Etzioni & Nunn, 1976), which became the basis of the bi–annual science indicator surveys of the US National Science Foundation (NSF) from the late 1970s onwards. A regular audit of the nation's scientific literacy was undertaken using representative surveys of the adult population.

The research agenda

The psychometrics of factual knowledge is a key problem of this paradigm. Knowledge is measured by quiz–like items. Respondents are asked to decide whether a statement of a scientific fact was true or false, where scientific authority is in the position to determine the correct answer. Some of these items became notoriously famous and travelled between the surveys in many countries and hit the news.

Table 2: Examples of knowledge and attitude items in literacy research

Knowledge items

Item 1. 'Does the earth go around the sun or does the sun go around the earth', (**the earth goes around the sun**; the sun goes around the earth; dk).

Item 2. 'The centre of the earth is very hot' (**true**, false, dk)

Item 3. 'Electrons are smaller than atoms' (**true**, false, dk)

Item 4. 'Antibiotics kill viruses as well as bacteria' (true, **false**, dk)

Attitude items (Likert scales)

Item 5: 'Science and technology are making our lives healthier, easier and more comfortable' (agree = positive)

Item 6: 'The benefits of science are greater than any harmful effects' (agree = positive)

Item 7: 'We depend too much on science and not enough on faith' (disagree = positive)

1 strongly agree;
2 agree to some extent;
3 neither/nor;
4 disagree to some extent;
5 strongly disagree;
9 don't know (DK).

Source: Eurobarometer 31 of 1989.

Respondents score a point for every correct answer (highlighted in table 2). It is a research problem to formulate such short statements for which the correct answer can be determined without too much controversy, and to get a good mix of relatively easy and difficult items, and from different fields of science. The empirical fact that many of the responses to these items, often between 10 or 20, are correlated needs to be constructed to obtain a reliable index of factual knowledge. Such an indicator can then be used as scalar variables in further analysis. Most research concerned itself with the proposal of such items and the scalar value of these items. More recently ideas of item response theory are brought into the discussion (Miller & Pardo, 2000) . There has been a tension between the research purpose of these items as part of a scale and their news value as single items. As literacy indicators these items only take value in combination with others; stand alone any single one has little significance. However, the mass media have repeatedly picked-up single response distributions as indicators of public ignorance and reasons for public outcry, in particular the item about the helio-centric worldview (item 1 above in table 2) has a history of alarmist citation out of context.

What counts as scientific knowledge? Miller suggested two dimensions of knowledge: facts and methods. This stimulated efforts to operationalise 'methodological knowledge' such as probability reasoning and experimental design, or the importance of theory or hypothesis testing for research. To create survey items for scientific methodology is a greater challenge than for factual issues. Scales of methodological knowledge are still based on three or four items, and therefore much less reliable than those of factual knowledge. Useful in this context is an open question initially suggested by Withey (1959) : 'Tell me in your own words, what does it mean to study something scientifically' . Respondents' answers are recorded verbatim and coded for an index of methodological and institutional awareness. However the manner of the coding the responses remains controversial (see Bauer & Schoon, 1993) .

Confusion over method and content has been a characteristic of the literacy paradigm. Critics hve argued that the essence of science are its methods and not its facts (e.g. Collins & Pinch, 1993) . Therefore awareness of things like uncertainty, peer reviewing, the settling of scientific controversies, and replication of experiments should be reflected in the assessment of literacy. Furthermore, it is argued that scientific knowledge includes knowledge of the scientific institution and its politics, what Prewitt (1983) called scientific savvy. The latter dimension of literacy has to date received little empirical attention (e.g. Bauer, Petkova & Boyadjjewa, 2000) .

The appreciation of 'positive outcomes' of science is measured by attitude scales. Respondents agree or disagree to a number of statements, and thereby express their positive or negative attitude towards science. Lists of such items (see examples in table 2 above) include statements that, in order to assess a positive attitude, require the respondent to disagree, others to agree depending on the formulation. This tactic avoids random results that arise from the tendency of mass respondents to agree to any statement, the so-called acquiescent response bias. A General issue related to such scales is the inclusion of a separate neither/nor and 'don't know' option. Excluding the neither/nor may create more variance in the data, but forces people into a position which they don' t hold with no space to express real ambivalent attitudes.

Another issue of literacy is how to assess literacy: a continuous score or a threshold measure. Miller's original proposal was a threshold measure and considered a determinant of the 'attentive public for science' , which is the sector of the public that is knowledgeable of, interested in and feels informed about science and technology. The literate person shows some knowledge, some appreciation of method, rejects superstition, and has a positive attitude towards science, and is more likely to be part of the attentive public for science, assuming that knowledge, interest and awareness form a complex. Be that as it may. One issue arose over the reported results. The definition of this threshold measure seem to change from audit to audit, and it was not clear whether changes in literacy reflected changes in definition or in substance (see e.g. Beveridge & Rudell, 1998) . An coherent analysis of the scares time-series data on scientific literacy available across Europe and in the USA is still a task waiting to be done.

Instabilities in the definition of literacy hinges on the last point of research, the establishment of indicators for international comparisons. Since the 1980s a number of countries have fielded similar audits of adult scientific literacy, data exists from the USA, Canada, China, Brazil, India, Korea, Japan, Bulgaria, Switzerland, Britain and France and many other EU countries, but the availability of this data for analysis remains a problem. [2] The US NSF has in many of their reports presented comparative analyses offering a 'horse race' ranking of different countries' literacy and answering the question:

and where do we stand? A key problem of such comparisons remains the fairness of the indicator. It is likely that the particular mix of knowledge items may be biased towards certain countries. Countries have a different science base, and adult literacy is likely to reflect awareness of the country's science base (e.g. Raza et al, 1996). The issue of functionally equivalent literacy measures remains an open issue.

What is to be done?

The literacy paradigm is best characterised by its concern with the public deficit of scientific knowledge. It focuses on the operationalisation of knowledge, and the NSF opened the space for international comparisons of adult science literacy indicators during the 1980s. Following in the tradition of general literacy, interventions are in the area of education. Deficits in adult scientific literacy is a matter of continued education, and requires increased efforts and time for science in the school curricula and publicly responsible mass media reportage on science and technology (e.g. Royal Society, 1985).

Critique

The critique of the literacy paradigm focuses on conceptual as well as empirical issues. The first is the legitimacy of 'scientific literacy'. Why should science be special and qualify for state funded auditing of the public's awareness? What about historical literacy, accountancy or legal literacy? Equal arguments can be raised for the significance of these forms of specialised knowledge in modern life. No household can run without some accountancy; historical consciousness is part of the life of a nation. The case for 'science literacy' remains to be made in competition to other types of literacy.

Secondly, the status of the knowledge measured in large scale survey research is controversial. Critics have argued that this type of measure produces at most irrelevant indicators of 'textbook knowledge', at worst empirical artefacts. Of real importance is contextual knowledge of science that emerges in local controversies and reflects people's life concerns and their social relationships (Simon, 1991; Irvin & Wynne, 1996). The British ESRC research programme on Public Understanding of Science between 1986 and 1991 was hopelessly entrenched in methodological conflict over how to study the public understanding of science. [3]

Thirdly, there is the question of astrology. Does belief in astrology disqualify a respondent from being scientifically literate, as Miller suggested in 1973? This issue raised considerable concern, and may reflect cultural sensitivities in the USA. It was argued that the co-existence between usage of astrology and science literacy is an empirical issue, and should not be a matter of definition of literacy. Contradiction or tolerance between traditional and modern forms of knowledge may be a cultural fact and a matter of empirical research. Astrological and scientific practice go together in many parts of the world, as these knowledge systems serve different functions in life. To make 'astrology' a negative criterion for science literacy would exclude the analytically interesting cases of tolerance between these types of knowledge (see Boy & Michelat, 1986; Bauer & Durant, 1997).

Finally, it is suggested that the concern for literacy arises in parallel with 'big science' programmes and their lack of public legitimacy. The idea of increased literacy to bridge the gap between science and the public assumes a fundamental gap in the cognitive operations of literate scientists and an illiterate public, for which there is little evidence. Furthermore, if the Baconian notion of 'knowledge = power' holds, any attempt to share knowledge without public empowerment can only create further alienation rather than raprochement. Literacy is therefore the wrong answer to the problems that arise between science and the public (Roqueplo, 1974; Fuller, 2000).

(To be continued)