The Public Understanding of Science

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Both in Britain and the United States the public says it is more interested in science than (for example) sport. Public knowledge of science gives less cause for gratification.

WHY should anyone care about the public understanding of science? First, science is arguably the greatest achievement of our culture, and people deserve to know about it; second, science affects everyone's lives, and people need to know about it; third, many public policy decisions involve science, and these can only be genuinely democratic if they arise out of informed public debate; and fourth, science is publicly supported, and such support is (or at least ought to be) based on at least a minimal level of public knowledge. Whether or not the difference between public understanding and public ignorance of science is, as Isaac Asimov has claimed[1], "the difference between respect and admiration on the one side, and hate and fear on the other", common sense suggests that the scientific community would be unwise to presume upon the continued backing of a public that knows little of what scientists do.

So, how much science does the general public understand? The answer that emerges from our research in Britain and that of Professor Jon Miller and his colleagues in the United States is 'not much'. According to the results of two parallel national surveys, carried out in the summer of 1988, levels of British and American public *interest* in science, technology and medicine are relatively high; but levels of *knowledge* of each area are far lower. Although an impressive 66% of British and 62% of American respondents clearly understood the implications of simple probabilistic statements, only 34% of Britons and 46% of Americans appeared to know that the Earth goes round the Sun once a year, and just 28% of Britons and 25% of Americans knew that antibiotics are ineffective against viruses. Equally striking, in the context of current public and political concern about technology and the environment, is that only 34% of British respondents knew that nuclear power stations are not a source of acid rain, whilst a mere 23% recognized a link between the burning of fossil fuels in coal-fired power stations and the problem of global warming.

Several previous studies have investigated public perceptions of science and technology[2-4], the most systematic of which have been the US National Science Foundation (NSF) *Science Indicators* survey series conducted by Miller over the past decade[5-8]. In general, previous survey researchers have concentrated on public attitudes towards technology. For this reason, we have developed a range of new questions which, in combination with existing measures, permit us to explore the public understanding of science and science-based technologies (including medicine). At the same time, we have collaborated with Miller and his colleagues in establishing a limited area of overlap between our own and the *Science Indicators* survey series with a view to international comparison.

Stratified random samples of 2,009 British and 2,041 Americans adults over the age of 18 were interviewed in late June and July 1988. The results make sobering reading for politicians and civil servants with an interest in science policy, for scientists with an interest in their public constituency, and for educationalists with an interest in the dissemination of scientific learning. For brevity and clarity's sake, we shall concentrate here on Britain, making reference where appropriate to comparable data from the US *Science Indicators* study. Full details of the comparison are available elsewhere[9].

We begin with interest, because this represents a basis for an individual's cultivation of understanding and the formation of attitudes (Table 1*A*). Respondents were asked to say how interested they were in six different issue areas in the news. Easily the highest level of self-reported interest is that for new medical discoveries; next come the levels for new inventions and new technologies and scientific discoveries; and after these (in descending order) come those for sport, new films and (predictably, perhaps) politics. The pattern in the United States is broadly similar, except that there are consistently slightly higher levels of self-reported interest in science, technology and (especially) medicine.

These results are quite surprising. As a check on their reliability, British respondents were asked to say how likely it was that they would read newspaper stories under a variety of different headlines (Table 1*B*). Medical stories (headlines *c* and *l*) are clearly in the lead, together with an item on government cuts; and once again, scientific and technological stories (headlines *d*, *f*, *g*, *i* and *k*) also have a very strong following.

In general, one would assume that people who are interested in a particular issue will tend to be relatively well informed about it. We asked respondents to say how well informed they were about each of the self-report interest issue areas (Table 1*C*). As we had expected, self-reported interest and 'informedness' match pretty well for sport, politics and films; but for science, technology and medicine there is a substantial discrepancy: here, only a minority of those who report that they are very interested also claim that they are very well informed. As before, the pattern for the United States is broadly similar, with self-reported levels of informedness running consistently at a slightly higher level than those in Britain. For science, technology and medicine, it appears that many people perceive a gap between themselves and a world of learning about which they would like to know more.

So much, we may say, for the myth that most people couldn't care less about science. Of course, these results must be treated with caution. Simple declarations of interest are easily made, and it is possible that they represent what respondents thought they ought to say rather than what they actually felt. We were careful to ask the interest and informedness questions before respondents were aware of the purpose of the interview; but even so, people possibly felt pressured to give false answers. That this was not a serious problem is suggested by the fact that the self-report results hang together well and relate sensibly to other measures. Respondents who said they were very interested and very well informed tended to be better educated, and (as we shall see) tended to perform better in objective assessments of scientific understanding.

The independent assessment of understanding is at the heart of our inquiry. We measured scientific understanding on two main dimensions: understanding of the processes of scientific inquiry (henceforth, process); and knowledge of the elementary findings of science (henceforth, knowledge). In combination, we believe that process and knowledge provide a reasonable index of scientific understanding. Of the two, process is by far the trickier to deal with — the issues are more abstract and less clear-cut, and the task of formulating sensible and serviceable questions is inherently difficult.

We adopted a two-part question that has occupied an important place in the NSF survey series. British respondents were asked whether they had a clear, a general, or little sense of what it means to study something scientifically; and respondents falling into the first two categories were then asked to state in their own words what it means to study something scientifically. The resulting statements were recorded verbatim and then placed into one of four categories (see Table 2, question *a*). The results make rather gloomy reading for anyone who takes seriously the conventional, quasi-popperian model of scientific method. For in their answers less than 14% of respondents made any mention either of theory construction and hypothesis testing, or of the experimental method. These results are broadly consistent with the findings of the NSF survey series.

Before concluding that only a small minority of British adults have any grasp whatever of the roles of theory and experiment in science, we should reflect on the sheer difficulty of this item. Arguably, the question measures linguistic as much as scientific skills; certainly, it ignores the possibility of tacit public understanding of the processes of science.

To get round this problem, we devised a number of questions which required respondents only to recognize and not to state the right answers (Table 2). In general, the results point to considerable tacit public understanding of the processes of scientific inquiry. Although fewer than 14% of respondents mentioned experimentation unprompted, more than 56% opted for the experimental approach when given a choice between alternative methods of investigating a problem (Table 2, question *b*); and although fewer than 4% mentioned theory construction and hypothesis testing unprompted, more than 55% disagreed with the proposition that '*All* of today's scientific theories will still be accepted in a hundred years' time' (Table 2, question *f*).

As well as assessing our respondents' grasp of the processes of scientific inquiry, we wanted to find out how scientifically knowledgeable they were. For this purpose the quiz shown in Table 3 was devised. One notable point about this battery of more than 20 factual items is its extremely elementary nature. To be sure, one or two items (such as 'Hot air rises') were included as morale boosters in the expectation that virtually everyone would get them right; but the remainder were selected to fall within the range of significant variation in public understanding of science.

A subset of 15 quiz items from the British study was also included in the US survey. Where 31% of British respondents knew that electrons are smaller than atoms, the comparable figure in the United States was 43%; and where 34% of British respondents were able to state correctly both that the Earth goes round the Sun and that it takes a year to do so, the comparable figure in the United States was 45%. In case these figures should appear overly flattering to the American public, it is worth reporting that where 74% of British respondents knew that some radioactivity occurs naturally, the comparable figure for the United States was 65%; and where 46% of British respondents knew that the earliest human beings did not live at the same time as the dinosaurs, the figure for the United States was 37%. Overall, American scores on the 15 quiz items fielded in both countries

TABLE 1 Measures of interest in and informedness about science and technology

TABLE 1*A* Self-reported interest

		Very interested	Moderately interested	Not at all interested
a	Sport in the news	27.9	42.9	29.2
b	Politics	16.2	54.7	29.1
c	New medical discoveries	49.0	40.9	10.1
d	New films	17.2	38.3	44.5
e	New inventions and technologies	39.4	45.0	15.6
f	New scientific discoveries	38.2	44.0	17.8

TABLE 1*B* Self-reported interest in newspaper headlines

		Definitely read	Might read	Definitely not read	Don't know
a	Heathrow Robbery and Drugs Deal	54.7	37.8	5.2	2.2
b	East Enders Star in Baby Shock	16.6	31.5	44.2	7.6
c	New Clue in Hunt for AIDS Cure	63.1	26.5	8.2	2.2
d	Robots for Housework Soon	20.1	35.6	33.2	11.2
e	FA Cup Winners Surprise	29.6	25.4	37.3	7.7
f	Can Pesticides in Rivers be Controlled?	46.7	32.5	12.7	8.2
g	Government Backs Massive Investment in Science	38.5	36.7	16.3	8.5
h	UN Calls for British Action Against South Africa	38.7	34.0	18.4	9.0
i	Astronomers Discover New Galaxy	40.7	29.9	21.9	7.5
j	60's Pop Idol in Comeback	15.8	34.4	37.6	12.2
k	"Was Darwin Right?" Say Scientists	33.2	33.4	20.8	12.7
l	Heart Disease Our Own Fault Claim Experts	68.5	24.3	5.0	2.2
m	New Government Cuts Announced	66.6	24.4	6.3	2.8

TABLE 1*C* Self-reported informedness

		Very informed	Moderately informed	Not at all informed
a	Sport in the news	28.3	41.8	29.8
b	Politics	16.8	54.8	28.3
c	New medical discoveries	9.9	54.8	35.1
d	New films	11.5	36.0	52.4
e	New inventions and technologies	9.4	52.9	37.6
f	New scientific discoveries	9.0	47.5	43.3

All scores are percentages. The final measure of interest was constructed using six items (Table 1*A*, questions *e* and *f*; 1*B*, questions *f*, *g*, *i* and *k*). These were the items that loaded most heavily on the first, unrotated principal component of a principal components analysis of all the interest items. The medicine items (1*B*, questions *c* and *l*) loaded rather weakly with science; and on a rotated solution, they loaded on a separate dimension with items *a* and *m*. This suggests that interest in medicine is distinct from interest in science.

The six science items were then aggregated to form a scale. Responses in 1*A* were scored 3 points for 'very interested'; 2 points for 'moderately interested'; and 1 point for 'not at all interested'. Responses in 1*B* were scored 3 points for 'definitely read'; 2 points for 'might read'/'don't know'; and 1 point for 'definitely not read'. The maximum score on the scale is 18, and the minimum score is six. The mean for the scale is 10.66 and Cronbach's Alpha reliability coefficient is 0.80.

were on average slightly higher than British scores. In the public knowledge of science stakes, it appears that the United States leads Britain by a short head — but we rather doubt whether these figures give much cause for celebration on either side of the Atlantic.

The attempt to measure scientific understanding on two dimensions rests on the assumption that process and knowledge do indeed constitute meaningful components of a single, larger construct: scientific understanding. This assumption is supported by our results, which reveal a close association (by the standards of social survey research) between our aggregate process and knowledge measures ($r = 0.68$). This association justifies the further aggregation of the two scales into a single scale of 27 items (Cronbach's Alpha reliability coefficient = 0.84). It is this larger understanding scale that will be used for further analysis.

What sorts of people tend to know more about science? Using a number of standard socio-demographic measures, and deriving zero-order correlations with scientific understanding, we find that in Britain younger people tend to know more than older people; males tend to know more than females; and middle-class people tend to know more than working-class people. The strongest association of all is between educational level and scientific understanding. Significantly, the same (though generally weaker) pattern of associations emerges between socio-demographic variables and interest in science and technology. Finally, there is a reasonably strong association between interest and understanding ($r = 0.49$).

This is the same broad pattern of associations that has been a consistent feature of the NSF survey series, and in neither case are the results surprising. For example, so far as age is concerned it would be astonishing if the radical improvements in education that have taken place over the past two generations had not left at least some sort of mark on the public understanding of science; and in connection with sex, it is regrettably a commonplace that in our culture women tend to be less interested and involved in science than men. This being said, it is important to establish these associations, not least in order that we can direct education and other forms of public scientific communication more accurately.

How do these results, briefly sketched here, speak to the reasons for caring about public understanding of science with which we began?

On the question of science as a cultural achievement, there is clear cause for concern. Some of the questions about knowledge addressed elementary but fundamental aspects of the scientific world-picture, yet they defeated a majority of respondents. That most of the public do not know of the achievements of J.J. Thomson, Robert Millikan and Niels Bohr (Table 3, question *i*) may perhaps be explained on the grounds of the relatively esoteric nature of atomic physics; but what excuse shall we give (not for the public, but for ourselves as scientists and educators) to account for the fact that most of the public appears not to have caught up with Nicholas Copernicus and Galileo Galilei (Table 3, questions *u* and *v*)? If modern science is our greatest cultural achievement, then it is one of which most members of our culture are very largely ignorant.

As regards practical reasons for caring about the public understanding of science, we find a similar picture. Although our survey was not intended primarily to discover how well the British work-force is equipped for life in an economy dependent upon science and technology, the fact (based on ancillary questions in the survey, not shown in the tables) that only between a quarter and a third of our respondents were able to give a minimal account of the difference between computer hardware and software does not augur particularly well. Even more

TABLE 2 Measures of understanding of processes of scientific inquiry

a	What does it mean to study something scientificially? Answers including reference to:	
	Theory construction	3.2
	Experimental method	10.5
	Other answers	43.1
	Don't know/Not anwered	43.2
b	Suppose a drug used to treat high blood pressure is suspected of not working well. On this card are three different ways scientists might use to investigate the problem. Which *one* do you think scientists would be *most* likely to use?	
	(i) Talk to patients to get their opinions	12.5
	(ii) Use their knowledge of medicine to decide how good the drug is	26.5
	(iii) Give the drug to some patients but not to others. Then compare what happens to each group	56.3
	(iv) Don't know	4.4
c	When scientists talk about Einstein's theory of relativity, are scientists talking about	
	(i) A hunch or idea	11.2
	(ii) A well established explanation	33.3
	(iii) A proven fact	39.1
	(iv) Don't know	16.4
d	And when they talk about Darwin's theory of evolution, are scientists talking about	
	(i) A hunch or idea	19.7
	(ii) A well established explanation	44.6
	(iii) A proven fact	21.1
	(iv) Don't know	14.7

e	Doctors tell a couple that their genetic make-up means that they've got a *one in four* chance of having a child with an inherited illness. Does this mean that	Yes	No	Don't know
	(i) If they have only three children, none will have the illness?	4.9	84.2	10.7
	(ii) If their first child has the illness the next three will not?	9.3	80.3	10.3
	(iii) Each of the couple's children has the same risk of suffering from the illness?	82.1	9.6	8.0
	(iv) If their first three children are healthy, the fourth will have the illness?	8.6	80.3	10.9

		Agree strongly	Agree slightly	Neither agree, nor disagree	Disagree slightly	Disagree strongly	Don't know
f	*All* of today's scientific theories will still be accepted in a hundred years' time	7.1	16.9	13.5	30.4	24.9	7.3
g	New technology does not depend on basic scientific research	3.8	21.8	16.5	29.3	17.3	11.5

All scores are percentages. The final process scale was constructed using all seven questions. Answers to question *a* were coded into four categories: (i) answers referring to science as a process of theory construction and hypothesis testing; (ii) answers referring to the notion of experimentation, but not mentioning the testing of theories or hypotheses; (iii) other, often rather vague answers referring to science as a process of fact gathering, or mentioning concrete scientific procedures (looking down a microscope, for example); and (iv) respondents who did not qualify for the question (see main text), or who when asked replied 'don't know'.

These categories were used as a four-point scale, with category (i) scoring 3 points and category (iv) scoring 0. In question *b*, respondents choosing options (i) and (ii) or don't know' scored 0 and those choosing option (iii) scored 1. In questions *c* and *d*, respondents choosing options (i) and (iii) or 'don't know' scored 0, and those choosing option (ii) scored 1. In question *e*, respondents who stated that option (iii) was correct and that all other options were incorrect scored 1 (the number scoring 1 on this criterion = 66%). In questions *f* and *g*, those disagreeing with the propositions scored 1.

A principal components analysis of the process measures showed them to possess only a single major dimension. The process scale has a maximum score of 9 and a minimum score of 0. The mean score is 3.76, and Cronbach's Alpha reliability coefficient is 0.61.

worrying, in the quiz more than half our respondents asserted that antibiotics kill viruses as well as bacteria, while almost 70% believed that natural vitamins are more efficacious than laboratory-made ones.

We turn next to what might be termed the democratic argument for promoting the public understanding of science. What are the prospects for informed public debate and decision-making when a large proportion of the public is confused about most of the relevant facts? For example, consider some results from another question not included in the knowledge quiz. We asked whether nuclear power stations cause acid rain. Almost 50% of respondents said they did, and only 34% said they did not.

This result is strongly related to scientific understanding. Only 11% of respondents in the top quartile of scientific understanding believed that nuclear power stations cause acid rain, whereas the figure for the bottom quartile is 62%.

Though impressively strong, this relationship between knowledge of the environmental effect of nuclear power stations and scientific understanding is not in itself particularly surprising. After all, knowledge about nuclear power is itself a part of scientific understanding. What the result does show, however, is that our general understanding scale is measuring variability that is directly relevant to specific science-related public policy issues.

Finally, there is the question of the relationship between public understanding and public support for science. Our survey contains a large number of measures of attitude. Preliminary analysis of results on these measures indicates that there are important relationships between public understanding and public attitudes, with a tendency for better-informed respondents to have a more positive general attitude towards science and scientists; at the same time, however, it indicates that it is unwise to generalize to any particular conclusions concerning public attitudes towards specific scientific or science-related public policy questions. This being the case, we shall say no more here about Asimov's image of a largely uninformed public caught between hatred and fear of the scientific community. The results we have provided indicate that although the public is largely uninformed, it is also largely interested in science. This is surely a cause for optimism about the scope for improving the public understanding of science. ☐

TABLE 3 Measures of scientific knowledge

		True	False	Don't know
a	The centre of the Earth is very hot	86.3	3.8	8.3
b	All insects have eight legs	7.9	83.7	8.3
c	The oxygen we breathe comes from plants	59.9	28.3	11.8
d	Radioactive milk can be made safe by boiling it	12.9	65.1	22.0
e	Lasers work by focusing sound waves	20.1	41.8	38.0
f	Sunlight can cause skin cancer	93.5	3.2	3.2
g	Hot air rises	96.7	1.2	2.0
h	The liver makes urine	25.4	53.1	21.4
i	Electrons are smaller than atoms	30.9	23.5	45.3
j	The continents are moving slowly about on the surface of the Earth	71.7	8.1	20.1
k	The future children of a body builder will inherit the benefits of his training	12.7	76.7	10.7
l	Diamonds are made of carbon	58.9	15.5	25.3
m	It is the father's gene which decides whether the baby is a boy or a girl	51.2	26.1	22.5
n	Antibiotics kill viruses as well as bacteria	54.5	28.6	16.7
o	Natural vitamins are better for you than laboratory-made ones	69.6	17.7	12.6
p	Common table salt is made of calcium carbonate	36.5	31.1	32.3
q	The earliest humans lived at the same time as the dinosaurs	31.6	46.2	22.1
r	Which travels faster — light or sound?			
	Light travels faster		74.7	
	Sound travels faster		18.5	
	Don't Know		6.6	
s	Nuclear power stations produce radioactivity. Is *all* radioactivity man-made or does some radioactivity occur naturally?			
	All man-made		9.2	
	Some naturally occurring		74.3	
	Don't know		16.4	
t	Of the following things (a) Which is the largest? (b) Which is the next largest? (c) Which is the smallest?			
		Largest	Next largest	Smallest
	Solar system	14.1	25.2	5.4
	Galaxy	13.3	35.8	3.6
	Earth	6.9	5.8	71.8
	Universe	53.5	17.8	1.1
	Sun	5.0	5.2	10.2
	Don't know	6.9	10.0	7.8
u	Does the Earth go round the Sun or the Sun go round the Earth?			
	Earth round the Sun		62.8	
	Sun round the Earth		30.1	
	Don't know		7.1	
v	If the Earth goes round the Sun at *u*, how long does it take?			
	One day		16.2	
	One month		2.2	
	One year		34.1	
	Don't know		10.0	
w	When scientists use the term DNA, do you think it is to do with the study of			
	Stars		1.8	
	Rocks		1.8	
	Living things		43.2	
	Computers		6.9	
	Don't know		46.1	

All scores are percentages. Questions *a–s, u, v* and *w* were scored 1 point for a correct answer and 0 for an incorrect or a 'don't know'. Item *t* was scored 1 point for getting all three question parts correct and 0 for all other answers. The knowledge questions were subjected to principal components analysis, which revealed a single major dimension with no interpretable topic-specific or other minor dimensions.

A preliminary knowledge scale was constructed using all 23 questions. Cronbach's Alpha reliability analysis revealed that items *b, i* and *m* were not contributing to the reliability of the scale, and these were therefore removed. The resulting 20-item scale (the Oxford Scientific Knowledge Scale) has a Cronbach's Alpha reliability coefficient of 0.81. The scale is normally distributed, with a mean score of 11.44 and a standard deviation of 4.15.

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