To know science is to love it?

Observations from public understanding of science research

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Preface

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what kinds of revelations have the researchers come up with which those with immediate, practical concerns in the field might want to know about?

Over the last ten years, more and more people have come to spend some or all of their working hours trying to contribute to the public understanding of science. A smaller group have been working as academic researchers on the same topic. What kinds of revelations have the researchers come up with which those with immediate, practical concerns in the field might want to know about?

The articles collected here are the result of an invitation from COPUS to try and answer this question. There is, of course, an irony, that those whose research is relevant to questions of communication and understanding may not always get their findings across to others who would like to hear them. There is also an irony that many of those working to communicate science and the essence of scientific research should be less than conversant with the research findings in public understanding of science itself. But social research has its own special language and methods, just as natural science does, and a fresh eye may be able to offer a useful translation in either realm.

This small project was conceived as a hybrid. It began as an academic exercise, reviewing learned journals, searching databases, scouring conference programmes and mailing active researchers. One result was a bibliography of relevant work which is available separately (from COPUS). But the selection from this academic base was then made on essentially journalistic grounds. The pieces here are not a review of the field, in any academic sense. They are simply an attempt to highlight some topics where research seems to have something new to say, to tell some useful stories about the public understanding of science.

They also, no doubt, reflect my own biases about the field, which are to try and see things from the point of view of people who want to understand science, for whatever reason, and to recognise that knowledge is always transformed when it is communicated - as it has been transformed here. I have, of course, tried hard torender the research findings accurately, but the frames in which they are put might not be those in which they first appeared.

My thanks to all those who responded to calls for papers and other documents, and especially to Adrian Briggs, John Durant, Sally Goodman, Alan Irwin, Jill Nelson and Gillian Pearson, for advice and comment on drafts. Adrian Briggs also planned and executed all the preliminary research.
Any comments on the result would be very welcome, especially if they relate to topics which practitioners feel merit more attention from researchers. Please send them to copus@royalsoc.ac.uk

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To know science is to love it?

The scientifically informed are more discriminating in their judgements

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does greater understanding lead to greater sympathy?

One of the motives for trying to improve people's understanding of science has been to increase public sympathy for science and scientists, and perhaps give those trying to introduce certain new technologies an easier ride. But the implicit assumption that greater understanding leads to greater sympathy raises many questions, one being: does it necessarily follow that those who know more about, say, how gene therapy might be done, will be less fearful of a eugenic future?

The first point to make here is that this is probably the right way to ask the question. Few of us have a single, simple attitude to science. Rather, we have a complex, sometimes contradictory, set of attitudes and feelings towards varied manifestations of science and technology. This complexity extends to attitudes to work within particular fields. There is good evidence that people discriminate between genetic engineering in micro-organisms, plants, animals and human beings, for example. If we want to test the original assumption, there are at least two studies which appear to lend a little weight to the notion that "understanding" moves opinion toward the views on particular issues held by scientists.

One is a large-scale survey run in the US for the National Institute of Health in 1993. Jon Miller and colleagues at the International Centre for the Advancement of Scientific Literacy in Chicago asked two sets of questions which they used to derive indices of separate facets of scientific understanding - of basic biomedical concepts and of the nature of scientific inquiry. To be accounted knowledgeable about basic biomedicine, respondents had to give the correct answers to a couple of open-ended questions, and to true-false questions like: DNA regulates inherited characteristics for all plants and animals (true); all bacteria are harmful to humans (false); or the human immune system has no defence against viruses (false).

Probing the understanding of scientific inquiry is trickier as it is much less obvious what the "right" answers are. Miller's current solution is to use two more open-ended questions. One, used in previous surveys, asks people who say they understand how to study something scientifically to explain what they think this means. The other describes two ways of testing a new drug, with or without a control group, and asks why one way is better than the other. This time, the understanding being tested is whether the respondent sees science as requiring the development and testing of theories, and the role of controlled experiments in doing this. As is generally found in such studies, the proportion of people who were knowledgeable in either respect was fairly low. But the interest here is not so much in the absolute level as in the difference it makes to attitudes to policy issues which, in this survey, were animal experiments and Government support for basic research.

Earlier surveys typically show that Americans are roughly equally divided over whether scientists should be allowed to use animals like dogs or chimpanzees in experiments if the results are relevant to human health. This survey's attempt to see what made people more likely to answer one way or the other did suggest that understanding scientific inquiry, in Miller's sense, made people significantly more likely to support animal experiments. But this general understanding was less influential here than being older (and perhaps more worried about health problems), or being a man, and roughly on a par with being better educated.

Understanding biomedical terms, though, had no effect either way. The results on support for Government research spending were similar, except for the gender difference. The issue is quite different, of course, with more than four out of five people agreeing that "even if it brings no immediate benefits, scientific research which advances the frontiers of knowledge is necessary and should be supported by the federal government".

Educational level was again the dominant influence on favourable attitudes, with understanding of scientific inquiry some way behind, and specific biomedical knowledge having no real effect at all.

So there is some evidence here that some understanding goes with more positive attitudes to science, but the overall influence is not particularly impressive. An earlier study which shows that understanding can shift opinions comes from another American group, led by John Doble at the Public Agenda Foundation in New York. What they really showed was that, if a discussion is structured carefully enough, it is sometimes possible for lay subjects to develop what most scientists would regard as a reasonable view of an issue. The issues here were in that interesting region in between science and policy where so much of the debate about public understanding of science takes place. Global warming and disposal of solid waste were used as test cases because they matched three criteria: experts were concerned about public ability to grasp the issues; there were public opinion data which suggested widespread misunderstanding; and the underlying science was contentious.

They recruited a hundred people in four US cities to form what they call a "Citizen Review Panel". Each panel member completed a questionnaire about the two issues and the various policy options for dealing with them. Then they watched an educational video about solid waste disposal and discussed it in small groups. The same happened for global warming, and the second discussion was followed by a repeat of the opening questionnaire. The interest is obviously in whether the pre and post-session questionnaires give different results. As an extra comparison, leading US scientists were sent a similar questionnaire. The overall finding, for both issues, was that "after a brief period of study the views of our cross-section of respondents were strikingly similar to the views of leading scientists". This was due to an improvement in understanding but not only in the sense of possessing greater scientific knowledge such as the cause of the greenhouse effect. The project report argues that respondents also came to deeper understandings of the policy issues at hand "once they understood the basic issues to be decided and the benefits and risks of alternative solutions. The ingredient the public needed was a framework of choices, not a greater accumulation of facts".

Another finding underlines an important feature of this kind of experiment. The result depends on the issue under discussion. The study authors suggest that "public opposition to an unpopular notion may not change, no matter how much technical information people receive". The unpopular notion which showed this most clearly was the use of nuclear power. They comment that some experts suppose that if only the public understood that nuclear power is non-polluting, and does not contribute to greenhouse gas emissions, they would favour more nuclear generation. But many of this group, who apparently did understand this, nevertheless remained opposed to nuclear power which "seemed to rest on a combined emotional and intellectual assessment of many concerns, including the safe disposal of radioactive waste, the cost of nuclear power, a lack of confidence in the people who design and manage the power plants, and in the government's ability to regulate". In short, many respondents felt that "the history of nuclear power in the US is replete with bad faith". (See Chapter 2 for some related research).

These two studies, then, appear to suggest that more understanding can have some effects on opinion, but they are far from supporting the idea that public understanding equals acceptance. Other research evidence suggests that no such simple link is likely. In biotechnology, for example, one of the most detailed attitude surveys run in Britain to date found that the two groups with the strongest opinions, pro and anti, were the most knowledgeable of those investigated. This finding receives more general support from close analysis of the classic British survey of public understanding of science run back in 1988. Geoffrey Evans and John Durant recently published a further look at the attitude questions from this survey, in which they conclude that "the scientifically informed are more discriminating in their judgements". They are in favour of some kinds of research, but may be more strongly opposed to others than their less well-informed fellows. In the light of all these results, it seems plain that the equation between understanding and acceptance does not hold: or, perhaps, that "understanding" invariably goes beyond facts and figures and includes evaluative judgements.

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I'm from the Government, I'm here to help you

anyone who sees themselves as merely stating the facts may need to pause and consider how they may be seen by others - to think about what Brian Wynne calls the insitutional body language of scientific institutions

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people discriminate quite carefully when deciding which information sources to trust

If someone wants to know how to measure the speed of sound, any technically competent source will do. Once, such a request might have been demanding, even controversial. Now, there is a clear consensus how to approach the problem. But not many scientific questions of genuine public interest are like that. Typically, questions which are debated in public are contentious. Is this pesticide safe? What can we do about the ozone layer? Will new roads create new traffic? And the answers tend to stretch theory, to be at the limits of measurement, or to demand tenuous extrapolations from the known to the unknown. They may touch on ignorance as well as knowledge. In all such cases, who is giving the answer matters at least as much as technical competence.

In the really difficult cases this stems from the nature of the controversy. Camille Limoges and colleagues at the University of Quebec at Montreal have reviewed a set of public controversies to see, in part, what kind of communication is going on between experts and everyone else.

> One of their conclusions is that disagreement is often not related to matters of fact, but stems from deeper differences in definitions of what the controversy is about. He puts forward the idea that many different "worlds of relevance" may generate different interpretations of what looks from a distance like the same issue. Take one environmental dispute which ran in Quebec for several years in the early 1980s, which Limoges has studied. This looked quite simple at first. Should the Government go ahead with pesticide spraying to try and rid spruce forests of budworm? But the range of answers was not simple at all. In between a straight !yes" or "no" were answers like: get rid of the worm with a biological, not a chemical pesticide; try pheromone traps instead. Others saw the budworm as largely harmless, or a side issue, and criticised Government forest policies or industrial mismanagement of the forests. The same diversity of views can be found in other controversies, like the safety of genetically-modified organisms, food irradiation, water fluoridation and the possible health effects of electromagnetic fields from powerlines.

Even if real-life issues were not so complex, there is plenty of evidence that people discriminate quite carefully when deciding which information sources to trust on any particular topic. We all recognise the "they would say that, wouldn't they" response, but it can often be rather more sophisticated than that.

Look, for instance, at the responses when Lynn Frewer and Richard Shepherd of the Institute of Food Research in Reading asked 150 British people to evaluate information about genetic engineering applied to food production. Some were also asked who they would trust as sources of information on the topic. The findings here were in line with other studies, indicating that people say they would have quite a lot of faith in TV current affairs programme, quality newspapers, leaflets from a consumer organisation and scientific publications. They would, they thought, be much less likely to trust a food industry leaflet, a Government Minister's statement or (lowest of all) a tabloid newspaper.

This, like other studies, was an answer to a hypothetical question. But Frewer and Shepherd went one better and asked some of the people in their survey if they trusted the specific information given when it was actually attributed to specific sources. The results were interestingly different. For example, just over sixty per cent said that they would trust a report in a quality newspaper, but when apparently presented with one, fewer than half thought it trustworthy.

In fact, the attribution tended to reduce the differences in trust according to source. That is, there was little difference between hypothetical and actual trust for the low credibility source (government), but that of high credibility sources tended to fall when the question was real.

Nevertheless, the source of information seems established as an important potential influence on credibility, even though this study suggests that hypothetical and actual responses may show important differences. Certainly, the question of trust still looms large in much recent research, especially in relation to technological risks (see chapter 4 for other relevant research). Other studies have also produced unexpected findings, which reinforce the impression that the relations between trust in sources and information seeking are highly sensitive to the context.

A good example is the work of Alan Irwin and colleagues on attitudes to hazards in the neighbourhood of large chemical plants in Northwest England. Not surprisingly, they found a good deal of concern among local residents about the risks of the industry on their doorstep. "We're living on a time bomb. I bet there's more going on than we know", as one resident put it.

In addition, as the quote suggests, local people tended to regard the industry as the least trustworthy source of information. But at the same time, those who had actually sought information about chemical hazards had most often turned to the companies for help. Even though there was a suspicion that, for example, "they'd only tell you a load of blinding science to shut you up", people also saw industry as the only party who could actually do anything to reduce any hazard. And they asked the companies when they saw a problem.
The point is that these requests were made from a position of scepticism, or as the researchers put it; "the local culture encourages a critical evaluation of new information in terms of the social assessment of the trustworthiness (and degree of self-interestedness) of its source".

Two of the larger implications of this, and studies like it, for the way we think about public understanding of science are, as usual, about the contexts in which knowledge or information is placed. Although formal science is supposed to be universally true, communicating about particular issues means relating the science to immediate circumstances. Perhaps the greatest great achievement of the research system is to find ways of turning local knowledge (first elucidated in one laboratory) into global truths, accepted by all. But one prerequisite for effective communication between scientists and non-scientists is to find ways of turning those global truths back into local knowledge.

And when that knowledge touches on controversy, as it so often does, the sources will matter as much as the explicit content. Every organisation is constantly sending out messages about its view of the political and social world, which are inextricably interwoven with any efforts it may make to influence public understanding of science. And all of us are constantly making judgements based on these messages, judgements of interests, competence, and credibility. Anyone who sees themselves as merely stating the facts may need to pause and consider how they may be seen by others - to think about what Brian Wynne calls the institutional body language of scientific organisations. Like our personal body language, we may not be in complete control of it, but it is still worth recognizing that it is there whether we like it or not.

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Science is...?

...how Galileo decided that there must be mountains on the moon, or how Jenner came up with the idea that cowpox held the key to preventing smallpox

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"Well, first there’s an idea. Then it becomes a theory and then it becomes a truth. That’s basically the relationship. Truth is a much higher order, because you can always count on them".(College biology student, US, interviewed by Edmondson).

students’ views of how science gets done affect both the way they learn science, and their attitudes toward scientific knowledge

When it comes to understanding science, we all have ideas not just about particular areas of science, but about what it means to be scientific. And formal education may leave pupils with some impression on that score long after the details are forgotten. This is crucial because a good deal of research suggests that students’ views of how science gets done affect both the way they learn science, and their attitudes toward scientific knowledge.

For example, a recent review of evidence from educational studies involving college students by Katherine Edmondson and Joseph Novak of Cornell University supports both these conclusions.
Like much similar work, their studies point up problems with one traditional view of how science works. A particular, idealised notion of scientific knowledge still dominates much science education, they suggest. In this view, which they dub positivist after the earlier tradition in the philosophy of science with that name, scientists discover the facts about the world. Theories are unchanging once established, and offer certain knowledge, exact predictions.

This view implies that what students need to learn are a set of objective facts as timeless truths, which can be memorised. The rote learning which ensues is detached from other knowledge. The facts that may be retained are then less likely to be put into any wider framework, or made meaningful in the students’ own lives. Science remains something separate, something other.

They, and others, contrast this with an idea of scientific knowledge as more provisional, open to revision, and hedged with uncertainties. This approach, which Edmondson and Novak call constructivist, "posits a view of knowledge as a construction based on previous knowledge that continually evolves and does not exist independent of human experience".

The crucial point is that teachers and students who lean toward this view tend to adopt different approaches to science sessions. There is less rote learning, and more discussion of why particular theories take the form they do. They argue that such approaches foster more effective learning, in which scientific concepts are related to what may be learnt in other courses, or in everyday life.

Edmondson and Novak propose that laboratory work is a possible route into an explicit discussion of the basis of scientific knowledge, which could make science lessons more meaningful. As they put it, "while the lab section of a course provides an opportunity to underscore the active role of the learner in the generation of knowledge, it also presents the teacher with an opportunity to address larger... questions regarding the nature and permanence of truth, the role and origin of theories, and the integration of scientific knowledge with other forms of knowing."

As an alternative or, better, a complement to this approach to the lab, teachers might use more historical material in science courses. Some of the reasons for doing this have been explored recently in Britain by Joan Solomon and colleagues at Oxford University.

They worked with 11-14 year-olds in three different schools, first exploring what their images of scientific work might be. The premise was that naive ideas about how scientific knowledge is acquired are closely tied to particular images of research. And although responses to direct questions about this can be thin - as one pupil very reasonably pointed out; "I don't really know, I haven't met any scientists" most do have some idea what scientific work entails.

The Oxford researchers distilled a set of seven common images of science from responses to their questionnaires and interviews. They emphasise that most pupils held several of these images, and used them at different times, and that most involved a scientist actually doing something, making active use of an instrument or a piece of equipment. That is, they embodied some notion of how scientists go about getting to know about the world.

The images of scientists as people included the cartoon image of the scientist. They know that this is a cartoon - the white-coated, wispy-haired male doing something reckless with a giant chemistry set - but nevertheless it still influences ideas about how science works (or doesn't work). When the cartoon scientist, as they see him, does an experiment he has no idea what will happen next.

Next they record an image of the scientist as vivisectionist, "a syringe at the ready, always ready to inflict suffering on innocent animals". Again the children with this image saw a science where the (medical) experimenter has no real idea what will happen, and if the work goes wrong the animal probably dies.
In strong contrast with these images of scientists who do not really know what they are doing was the image Solomon calls the scientist as all-knowing. This is the scientist as seen in television documentaries, giving authoritative answers to important questions. In this world, scientists know things because most possible experiments have already been done, and they have the results.

Some pupils recognized an image of the scientist as technologist, agreeing with the suggestion that the reason for doing experiments is "to make things to help people". Interestingly, older students were less likely to respond like this, either because they felt that making "discoveries" was more important, or because they had concluded that not all technologies necessarily help people.

Those who believed they had met a scientist normally meant their teacher, which gives another different image of the purpose of experiments. School experiments typically have a correct outcome - which the teacher knows because he or she has done it before.

And if teachers can be scientists, maybe pupils can be, too. Again, the relationship with experiments changes. For most of us, doing science in school, experiments are exercises which have a right answer which we fail to deliver most of the time.

Finally, a few of the more sophisticated pupils had picked up an image of the scientist as entrepreneur. In this world, research was tied up with the search for valuable products, in competition with others. If it was not kept secret, it was liable to be copied by other scientists.

The sources for these ideas were plainly a mixture of experience in the classroom and within the wider culture. They were based on almost no experience of contact with genuine scientists. Their familiarity suggests that the seven images these British secondary school children had are probably widely shared.

Solomon's view is that these images will continue to colour these pupils' ideas about what it might mean to explain something scientifically, and that they should be introduced to some other ideas about the nature of scientific knowledge. She argues strongly that the way to get these ideas across in a way pupils will relate to in the same way as these pre-existing images is by offering stories about real, historical scientists at work, during the delivery of the normal science curriculum.

Tell them, for example, about how Galileo decided that there must be mountains on the moon, or how Jenner came up with the idea that cowpox held the key to preventing smallpox. Including stories like this, and related exercises, in normal science lessons over a whole school year did indeed seem to affect pupils' images of scientific practice. By the end of the year they were, for example, much more likely to think that the point of doing experiments is to arrive at an explanation of something, rather than to make discoveries.

This is a relatively simple change, but a powerful one. At the least, these pupils came away with a larger repertoire of images of scientific work. The images they already held were still there, but there were some new ones alongside. And as these images appear to express ideas about scientific knowledge, this may be a change which lasts. There is plenty of scope for discussion about which images one should try and convey, but Solomon's conclusion may hold generally: that stories of the actual activities of scientists are memorable enough to put across new ideas about the nature of scientific knowledge to young pupils.

This work relates to formal education, but it is worth pausing to ask what it might imply for people trying to portray scientific work in other contexts. Work on science journalism, for example, suggests that the taken for granted notions of the nature of science which appear in most journalists' copy are much closer to the positivist than the constructivist picture, in Edmonson's terms. Systematic analysis of the content of science news stories typically finds that such stories contain rather little explanation, but are strong on scientific authority.
And when you look at more ambitious journalistic effort magazine features, a typical way to frame the development of a scientific explanation is to tell it as a detective story. As Ron Curtis argues, this ties the story strongly to a very particular view of scientific method, moving "from unanswered questions to unquestioned answers".

Although education is probably a more powerful influence on people's ideas about the nature of science, it is worth asking what media stories like this contribute to public understanding, and whether we might do better.

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How safe is safe enough?

individuals are more realistic about risks, uncertainties and lack of complete control than the nuclear industry and regulatory authorities may realise

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"There's more radiation in farts" (Sellafield apprentice, 1993)

people have complex attitudes to technological risks, which express different kinds of ambivalence

The longer we all live, on average, the more we seem to worry about dying. So, at least it can seem when you look into studies of risk and perception of risk, a field which has grown very fast over the last two decades. The interests of risk researchers often extend beyond public understanding of science, but there are strong connections with several strands of research into understanding of science. After all, many of the risks which concern people in the modern world arise from the appliance of science. And it is always tempting for advocates of particular new technologies to ascribe fears of the risks to "misunderstandings".

Not surprisingly, a major implication of the wealth of research on risk - mainly psychological and sociological - has been that this is too simple a view. As with science and technology in general, people have complex attitudes to technological risks, which express different kinds of ambivalence and are determined by a host of different factors in each case (see chapter 1 for other relevant research). From the wealth of new data, there are few large generalisations which stand close scrutiny, except that apparently simple findings are easy to misinterpret.
This is not necessarily bad news. It may make it harder work to arrive at a well informed appraisal of public conceptions of a particular issue, but the results may also show that people concerned are less risk averse, or at any rate more realistic about risk, than is often supposed.

> To choose just one issue from a host of possibilities, what are we to make of the finding that the local population around a nuclear installation may have more favourable attitudes toward nuclear power than the public at large? Possible explanations might be that the people who have nuclear neighbours have been selected over the years to be those who willingly tolerate any associated risks. Alternatively, their views might be evidence of a well-established effect in risk-perception: we may tend to see things as risky for other people, but not for us.
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> Or, it might be that those who live next door to a nuclear plant know more about it than people elsewhere. This is an interpretation which the industry has tended to favour. When residents of West Cumbria are polled

about their views on nuclear power and radioactive waste disposal, for example, they are found to have more faith in the nuclear industry and its regulation than the rest of us.

But is this due to a better understanding of how the industry works, born of long experience of the neighbouring Sellafield reprocessing plant? Brian Wynne and his colleagues at the University of Lancaster suggest not. Rather, they suggest, there is "extensive local public ignorance about the operations and processes used at Sellafield. Far from it being the case, as is sometimes claimed, that local acceptance of the industry rests on a greater-than-average understanding of nuclear power and its implications, such acceptance rests more on a fatalistic acceptance of the dominant local economic and employment role of Sellafield, with the accompanying risks, in the absence of any realistic alternatives for the area".

The Lancaster group based this conclusion on the record of "focus group" discussions in Cumbria - that is, they listened at some length to what local people had to say about nuclear issues. And one of the things they said most often was that they felt generally powerless to affect the licensing or operation of the plant, one way or the other. The result was a combination of fatalism and anxiety, often resulting in a day-to-day denial of any problems. As one young mother put it, ÒI have my head in the sand when it comes to Sellafield. Until some big issue comes up and then I have my two penn’orth which doesn’t do any good anyway".

The overall findings show a large constellation of attitudes and feelings, grounded in the social and economic history of this relatively poor area over many years, and in experience of the style of the nuclear operators over several decades.

And while they find against the theory that people here are more knowledgeable about, and therefore more favourable toward, nuclear activity, equally important is their suggestion that locals are in many ways realistic about the hazards. They do not, on the whole, expect guarantees of absolute safety. As the authors put it, "individuals are more realistic about risks, uncertainties and lack of complete control than the nuclear industry and regulatory authorities may realise".

This matters, because if the nuclear companies and the authorities believe that there is a demand for blanket reassurances, they will try and provide them. But it may be that people neither want them, nor ever believe that they can be realistically given. If so, then offering them raises the suspicion that the industry is insulting people’s intelligence. Or, as the report of the study says, "the industry is tending continually to undermine its credibility with local people, by its insistence on giving an impression of comprehensive certainty or control." This suggests that people trying to manage public information about risk - nuclear or otherwise - can easily fall into a vicious circle. They believe that the public will be confused by uncertainty, and demand absolute assurances. This encourages a defensive approach which, in the case of Sellafield, makes it difficult to acknowledge leaks or other pollution incidents. This itself undermines outsiders’ confidence. If attempts to recover that confidence then rest on still more definite assertions of complete control, they make the problem worse, not better. If you want an example from a different field, just think of the controversy over BSE and the safety of British beef through the 1990s.

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Answering the wrong question

...when asked which order people would prefer to have the questions tackled, the professionals' intuitions were way off

the person who is actually trying to deal with the problem may have quite a different point of view

The basic rules for communicating about scientific subjects are really the same as those for communicating well in general. One of these which comes across particularly clearly in recent research is the one which says: know your audience. In particular, think hard about what they want to know. This is often difficult for people who have worked to acquire a particular expertise, as they will tend to see the problem in their own expert terms. But the person who is actually trying to deal with the problem may have quite a different point of view. Indeed, in practical terms the science involved may be scarcely relevant.

One especially affecting illustration of this is a recent study of Down's syndrome by David Layton of Leeds University. Down's syndrome can be defined scientifically in great detail, and doctors have access to this detail. What use, if any, is it to parents of a new-born Down's baby?

This is the question which Layton set out to investigate in his case study, one of four in a short book which also looks at use of home heating by the elderly, a local authority managing the risks of methane seepage from a waste dump, and radiation dangers at Sellafield.

The short answer is "not much". The researchers interviewed nearly 40 sets of parents, to discover the kinds of things they wanted to know about how to care for their new baby, with its unexpected needs. And the general finding was that what they were told bore little relation to what they needed to hear about.

Most, for example, were given a scientific account of the causes of Down's - involving an explanation of the appearance of a third copy of chromosome 21 instead of the normal pair, and the ways this can come about. The majority found this knowledge irrelevant. As one mother put it, "once we know what kind of Down's syndrome he's got, there's not much we can do about it and we've got to get on with things".

Getting on with things entails solving a host of practical childcare problems. Down's children tend to have poor muscle tone, for example, so often have difficulty sucking on a bottle. Later on, they may be slow to walk and talk, suffer frequent constipation or be insensitive to cold. All these present practical challenges, which may or may not relate to an area of scientific knowledge - anatomy and physiology, for example.

The researchers' general conclusion, after discussing many of these problems is that "for most parents their most potent resource was not formal science, the medical profession, ancillary services or even voluntary organisations. It was themselves". Parents built up a body of personal, practical knowledge which was a better guide to action than "high science". The experts, as well as often being discouraging about the children's prospects offered knowledge "in the wrong form, reflecting priorities different from those of practical action. Parents interpreted such experiences as evidence that those transmitting knowledge to them did not share their perception of the problem".

The most unfortunate aspect of this overall failure of communication, they suggest, is that the sources of medical and scientific advice tend to lose credibility with the parents, who thus don't acquire even the elements of a scientific understanding which would be useful.

There are many opportunities for less spectacular mismatches between the information on offer and what is actually needed. Another example comes from an American study by Melanie Myers and colleagues at the

University of Cincinnati and John Hopkins School of Medicine.
They were interested in how people who were going to have a genetic test for an inherited disease wanted the test handled by medical staff. In this case there turned out to be quite close agreement between professionals and consumers about what questions were important to answer . But when asked to predict which order people would prefer to have the questions tackled, the professionals' intuitions were way off.

What people wanted to know first was their chances of carrying one of the genetic alterations which can cause cystic fibrosis, the nature of the test, and their risks of having an affected child. Only then would they wish to discuss reproductive options, prenatal diagnosis and, finally, the effect that a child with cystic fibrosis might have on the family. Geneticists thought that people would want to know about this much earlier on, and predicted that they would only be asking about the test later on.

A simple moral here, then - that designing an effective counselling service demands asking people who are going to be using it. For Down's a much more detailed discussion of exactly what the problem is appears to be indicated. The saving grace, perhaps, is that when one focuses on particular problems like this, rather than discussing public understanding of science in general, the research evidence is that people will piece together what they feel they need to know somehow, though not always in ways the professionals would expect, or even approve of.

Yet another study of a genetic condition, in this case familial hypercholesterolaemia, by Helen Lambert and Hilary Rose, demonstrates this rather clearly. People with this disorder inherit a tendency to abnormally high blood cholesterol levels, and hence to heart disease. When diagnosed, they typically get advice about what to eat from their doctors, as a complement to drug treatment which lowers their blood cholesterol. But they put this together with information from many other sources: health education campaigns, the media in general, friends, family, and folklore. All of these contribute to the final set of decisions about how someone with the condition will manage their (and perhaps their family's) diet, to what they believe makes sense, and what is acceptable on their dining table. Most of this complexity is unseen by the doctors who offer the original, simple advice, but it is crucial in determining what actually happens.

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Toys for the boys?

there is common and increasingly unembarrassed talk amongst feminist scientists and engineers from different subjects and societies about how they feel they do science differently

Women report an identifiably different attitude to science from men

It is not huge, but as survey findings go it is pretty consistent. Women report an identifiably different attitude to science from men. Age and education affect views of science and technology, and the particular issue and local circumstances both have their influence. But the gender difference is there across the board. In a climate where governments are increasingly concerned about recruiting more women to scientific careers, quite aside from wider attitudes to science, it is interesting to look more closely at the precise nature of the difference.

Gender differences in responses to science have been much studied, as they fit snugly into a psychological tradition of study of gender differences in many other areas. Michele Trankina of St Mary's University at San Antonio recently reported a review of past surveys alongside her own new study from the US.

Her analysis of 18 years of US nationwide social surveys, from 1972 up to 1990, revealed that adult women of all educational backgrounds consistently displayed less confidence in science than men. Nearly half of men report a great deal of confidence in science, but among women the figure is only 40 per cent. Confidence increases for both sexes with educational level, but the gap appears to widen with more education. Among those without a high-school education, 37 per cent of American men but only 31 per cent of women have high confidence. Post high-school education lifts the figure to 63 per cent - almost two-thirds - among men, but only to 53 per cent for women.

Trankina followed up her review with a new study trying to probe more specific attitudes. She presented people with a series of statements about science, and found that women were more likely than men to agree with negative statements like, "science breaks down people's ideas of right and wrong", and "science pries into things". Neither belief seems likely to encourage women to pursue science as a career.

One set of reasons for these views is proposed by Susan Hornig in another recent American study. She recorded similar gender differences in attitudes to science and technology by probing responses to mock news stories about new developments. Women generally saw less benefit and more risk than men here. In follow-up interviews, their concerns focussed on the social implications of innovation.

The study also used the technique of assessing attitudes in detail by asking about agreement with a series of statements about science. Here, both men and women agreed that, overall, increasing scientific knowledge is a good thing. There was also close agreement between the sexes that science needs careful monitoring and control. But there were clear differences on questions about our dependence on science and the human costs of new developments. Women were more concerned than men about science as a means of control; about the motives of private companies doing research; and about technological unemployment. Men reported finding new developments more exciting, were more optimistic about technical fixes to social problems and wanted less testing of new products than women.

Hornig argues that these differences are not just evidence that women like science and its products less than men. She suggests that they should be interpreted as a positive statement, not a rejection of male-dominated science but an affirmation of other things in life. Women's culture, she believes, values relationships, family-life and the home, and the social over the technological.

If so, then it is a cultural difference between the sexes in present-day America which makes women less likely to be attracted to scientific careers. Two large problems arise for any simple scheme for recruiting more women into science. First, these differences plainly have deep roots, and are shaped by experiences from very early in life. Although it is not a study of gender differences, Joan Solomon, in a study of the interactions between the culture of the parental home and children's attitudes to school science has a telling vignette. She describes a diffident, taciturn 11-year-old girl, a newcomer to her school, suddenly showing a flash of assertiveness when asked about what she had been doing in science: "I'm not into science", came the reply.

Solomon's point here is that this kind of individual choice, whether gender based or not, is all-powerful. "School and the media can only present an invitation to knowledge: it is the children who, from quite a young age, deliberately accept or reject according to an internal sense of personal style". It seems likely that there are strong gendered influences on the formation of such a style.

The second issue is the implications for science. One standard tactic for encouraging women to consider the possibility of a scientific career is to offer role models - women who are already in research. But, aside from the fact that there are rather few of them in most disciplines and fewer still have high status, there is the question of what role they perform. If they are to research science the same way as their male colleagues, they may not inspire women who see science as alien to their gender's culture and values.

But if some aspects of science could be changed to accommodate the differing value set of potential female recruits, which ones would they be? And what would this do to the appeal of science for some of its more traditionally-minded male adherents? These remain open questions, but some feminist writers have tried sketching possible answers. According to the British sociologist Hilary Rose, "there is common and increasingly unembarrassed talk among feminist scientists and engineers from different subjects and societies about how they feel they do science differently". They, at least, do not see science as inextricably bound up with the domination of nature, but the studies summarized here suggest that many women do.

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Between knowledge and ignorance

visitors appeared to enjoy having their misconceptions addressed...it is more interesting to learn that you've had the wrong idea about something than to simply encounter a set of abstract facts

what is strictly speaking a "misunderstanding" in technical terms, serves people perfectly well

Public understanding of science researchers spend a lot of time debating what actually amounts to scientific understanding, and who gets to define what the correct understanding is. This may sometimes seem as much a political as a scientific question; or it may appear that what is strictly speaking a "misunderstanding", in technical terms, serves people perfectly well. After all, a working engineer will use numerous approximations which would make a stickler for scientific accuracy unhappy, but they may get the job done faster than adherence to the best available theory.

One thing which is clear from all this discussion is that there are many alternatives between a putative ignorance - simply not knowing about something - and a formal scientific knowledge which matches the professional's understanding of any particular subject. And it is also clear that a crucial factor influencing whether an audience acquire the kind of understanding an author intends is their prior notion of the subject. A strong tradition of educational research has grown up in the last 15 years or so which explores the ideas which schoolchildren may hold about phenomena before they are exposed to a more scientific account. Putting across a scientific understanding then requires actually bringing about theory change rather than simply supplying the right answer to an assumed question.

There seems no good reason to suppose that some adults may not share such informal ideas about scientific subjects. In considering this, it is important to say again that they may be internally coherent and, in their own way, satisfying. If a scientist would deem them misleading, they will make sense in the non-scientific context in which they are elaborated and applied.

A recent example which relates to an area of science of wide policy interest is a study by Robin Millar of York University on school students' understanding of ideas about radioactivity. He wanted to see if 16 year-olds could make the correct distinctions between three ideas - that something might "contain radioactive matter"; that it might "contain radiation" (the scientifically misconceived term); or that it might "be radioactive". The reason for fixing on these terms is that they express crucial aspects of the scientific understanding of radioactivity: action at a distance, for example, or the idea that irradiating something need not make it radioactive. The students were asked to apply the three terms across a range of contexts, including food irradiation, medical X-rays, use of radioactive tracers and measuring the thickness of paper.

These students, who covered different types of schools and social backgrounds, were typically quite happy to agree that items which had been irradiated would then "contain radiation". They generally preferred this term to either of the others. The implication, Millar suggests, is that many do not understand an aspect of physics which is often assumed to be fairly straightforward to teach, namely the difference between irradiation and contamination with radioactive material. He suggests that for many of the students in the study, "containing radiation" means the same as "has absorbed radiation", and goes along with the idea that the irradiated object will itself be a bit radioactive. As he says, "this may be of some significance for those who wish to understand or to influence public perceptions of technologies and processes which use, or are associated with, radioactive materials".

Millar's school students probably had no direct experience of radioactivity. Another study, with adults this time, shows how a complex set of ideas can grow up to help people make sense of their experience at work, in this case with electricity. Michel Caillot and Anh Nguyen-Xuan asked two groups of employees in France about electrical phenomena. One group came from the assembly shop of a computer company - where there were elaborate precautions to help stop static electricity damaging sensitive components. The employees worked chained to their benches by an earthed metal bracelet, for example. The other group worked for the French state electric supply company, EDF. Their accounts of what was happening when electricity did various things - electrocuted someone who touched a washing machine with a frayed lead, for example - incorporated a wide range of mental models in explanation.

There were, though, some common threads, such as the connected ideas that electricity is a kind of substance, a fluid, which can flow, pile up and be stored. In the end, it goes to Earth, seen as a "vast container into which electricity was dispersed or lost". There was also a tendency to see electricity as something which gets used up, and to treat alternating current as direct current. As I have already suggested, the authors stress that the models they exposed, while not scientific, enabled the people they were studying to make useful predictions when they were at work. They might not always be correct or consistent. but they came out right enough of the time to sustain the model. This means that company training programmes need to take the existence of such practically-derived models into account if they seek to put across a more reliable understanding of electricity.

If you can identify misconceptions among some target audiences, what can you do about them? One possibility comes from the Franklin Institute Science Museum in the USA. Researchers there have shown how hands-on exhibits with carefully worded labels can be used to alter people's ideas about gravity. Minda Borun and colleagues studied visitor's understanding of gravity before, during and after constructing their exhibits and labelling.

They identified five categories of popular misconceptions about gravity - that it depends on air, rotation, orbit, magnetism or the Sun. The two most frequent misconceptions, both held by 51% of visitors, were that gravity requires air or that it depends on rotation. So they tried to design exhibits to rectify these.

The "air" exhibit consisted of a glass tube with a ping-pong ball and vacuum pump attached so that visitors could see the ball fall when the tube was inverted either with or without air present. The exhibit was not, however, self-evident and testing the labels proved crucial to the success of the exhibit. Least successful was a label reading "Gravity does not depend on air". After reading this visitors were asked "What causes gravity?" and 29% said "Air pressure" compared with no references to air for the most successful label ("Gravity makes objects fall").

This shows, they suggest, that it is not enough to tell people about misconceptions, that negative statements are easily misread, and that labels need evaluation.

The air exhibit achieved a 47% improvement in understanding that air plays no part in gravitational effects. But there was also a 58% improvement in the number of visitors understanding the relationship between gravity and mass. This relationship had been explained in the text of the exhibit and the researchers believe that once people's misconceptions have been challenged they are receptive to learning new science information. They also comment that "visitors appeared to enjoy having their misconceptions addressed. It's more interesting to learn that you've had the wrong idea about something than to simply encounter a set of abstract facts".

So there are ways of building on a knowledge of misconceptions to develop programmes to correct them, where this is desirable - perhaps just because one feels people will enjoy knowing the proper scientific answer. But the diagnosis is crucial and, as the French study suggests, should include asking what use the supposed misconception is to those who hold it, otherwise, the non-standard ideas may show an unexpected tenacity in the face of educational efforts to eradicate them, however well-intentioned these are.

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Public Understanding of Science Practice

The Public Understanding of Science Practice series focuses on the public's perspective of science, engineering and technology, providing practical advice as well as food for thought for those involved in science communication. The series draws upon several public understanding of science research studies, identifying the chief findings of relevance to the practitioner, and pointing out those research techniques that might be used by the practitioner. Beginning with guidance on how to evaluate events for the public on science, engineering and technology, the series aims to add a new dimension to public understanding of science- an awareness of the public's point-of-view. To know science is not necessarily to love it.

COPUS is the Committee on the Public Understanding of Science of the Royal Society, British Association for the Advancement of Science and the Royal Institution.

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