1996 – 1997 ACADEMIC TRAINING PROGRAMME

LECTURE SERIES

SPEAKER : N. RUSSELL / Imperial College, London, GB
TITLE : Why and how to bring science to the public
TIME : 7 & 8 April, from 11.00 to 12.00 hrs
PLACE : Auditorium

ABSTRACT

I teach a Master's programme in Science Communication at Imperial College, London. The course is designed to take science graduates and postgraduates and retrain them in all aspects of communication and media work. They spend about half of their time on academic material relating to science communication. In these academic components they look at the nature of science, the nature of the media and the history and current practice of popular and professional science communication. Some of the key factors which we identify as governing the success or failure of science communication will be rehearsed in these two lectures.
How and why to bring science to the public

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Course Director: M.Sc. Science Communication

previously

• science curriculum developer with the Nuffield Foundation
• freelance science writer
• technical college lecturer in applied biology and science studies

and continuing

• student of the history of science and technology
Several reasons why the public might wish or need to be informed about science (COPUS 1985)

• *An economic reason.* The British economy is short of trained scientific and technological personnel.

• *A democratic reason.* Science and technology are issues of increasing importance and therefore people need to understand science and technology in order to take reasoned decisions on these issues

• *A cultural reason.* Science can bring pleasure and insight through an understanding of how the world works. People who cannot appreciate science are culturally deprived.
Linear model 1

Fundamental scientific research

New scientific knowledge

Technological innovation

Industrial application

Economic growth ➔ a fraction of economic surplus then ploughed back into more
Linear model 2

Fundamental scientific research

New scientific knowledge

Popularisation of this knowledge

General public are fascinated and see the benefits

Policy decisions informed by democratic consensus makes more funding available for
Players in the science communication game
one

Producers

Research scientists

Science teachers and lecturers

Science journalists and writers

Broadcast producers and editors
Players in the science communication game
two

Products

Research papers and patents

Reviews and textbooks

Popular science books

Conversations/interviews/presentations

Newspaper and magazine articles
Players in the science communication game
three

Consumers

Pupils and students

Scientists and technologists themselves

other professions making use of science
(e.g. doctors, engineers, civil servants)

lay audiences with special concerns
(e.g. patients and pressure groups)

general public
Struggling towards a concept map

- newspaper/magazine articles
- research scientists
- interviews
- journalists
- research papers
- textbooks
- popular science books
- science students
- teachers
- general students
The professional world of the science journalist

Principles of objective reporting

- detachment and neutrality towards matters reported
- lack of partisanship
- attachment to accuracy and other truth criteria
- lack of ulterior motive or service to a third party

However, in practice, values always tend to colour factual interpretations. Therefore what objectivity means in practice is hard to determine.
Defining terms for news

- About recent or recurrent events

- Unsystematic, dealing with discrete events; it is not a primary journalistic task to interpret or explain

- Transient - lasts only as long as the events themselves

- Unusual and unexpected - these factors dominate decisions about what is news, whatever the ‘real significance’ in social, political or economic terms

- Has ‘news-value’, based on subjective judgements about likely audience interest

- Is orienting and attention-directing - not a substitute for knowledge

- It is predictable
Defining terms of news-value

• Preference for events which fit advance audience expectation

• Bias towards the unexpected and novel but within the limits of what is familiar

• Continue with events already established as newsworthy and desire to balance different types of news event

• Foreign news interest is influenced by trading partners and international treaties

• In domestic news, while news values of unexpectedness and unusual dominate, they are much influenced by economic and political factors
Editors as news decision makers prefer events

- Having a short time span (being sudden)
- Having great scale and intensity
- Being clear and unambiguous
- Being unexpected
- Being culturally close to intended public
- Having continuity; being already news and consistent with past images and expectations
Over-riding determinants of media content

- A good steady supply of news, information and entertainment above all else

- A general failure to set things properly in context - the strict application of news values prevents proper investigation and explanation. Unfortunately, much science news involves explanation and therefore suffers.
Journalists believe events drive news interest but many media analysts suggest that news interest determines what events and noticed and reported.

\[ \text{Journalists} \]

\textbf{Events} \quad \text{News interest} \\
\text{News criteria} \quad \text{News criteria} \\
\text{News reports} \quad \text{Events} \\
\text{News interest (A consequence of the real world of events)} \quad \text{News reports (Events are chosen according to a social agenda)}
Science teaching - have we got it badly wrong?

- Students are failing to see the extent to which society is based on the practice and application of science and technology

- Students are failing to learn concepts considered essential for the intellectual competence of scientists

- Students are failing to understand the mechanics of scientific investigation

- Students fail to see that science-based problems in technology and society are scientifically under-determined and therefore can only be resolved (in the short term) with the aid of value-judgement interpretations
Academic science - have we got it badly wrong?

- Does science explore the wrong issues so far as the direct interests of the public and its various subgroups are concerned?

- For effective science communication, do scientists need to know more about the public than the public needs to know about science?
<table>
<thead>
<tr>
<th><strong>Science-in general</strong></th>
<th><strong>Science in particular</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook knowledge,</td>
<td>Bits and pieces of</td>
</tr>
<tr>
<td>reliable, acquired by</td>
<td>science, useful in</td>
</tr>
<tr>
<td>specialist practitioners</td>
<td>everyday circumstances</td>
</tr>
<tr>
<td>Positivist, authoritative objective</td>
<td>Rag-bag of elements which must be integrated into everyday problem set</td>
</tr>
<tr>
<td>Respected; scientists carry authority but are remote and inaccessible. Considerable folk understanding of the virtues of science</td>
<td>Science and scientists seen quite clearly to fail here, both in terms of their knowledge and how it is communicated</td>
</tr>
</tbody>
</table>
Case studies by Layton et. al. show just how irrelevant much science-in general can be for science-in-particular contexts

- The case studies refute the cognitive deficit model of science communication

- Scientific knowledge is not reliable in public contexts and customers must actively engage with it before they find it useful

- Science in the public domain seems incapable of giving a single right answer, whereas the supposed strength of science is that it does provide unequivocal right answers
Cognitive deficit versus interactive models

**Cognitive deficit**

- Science
  - Citizens

Science is coherent, objective, unproblematic, well-bound

Science is central to decisions about practical action in everyday life

Science is unencumbered with social or institutional connections

Uptake of science is determined by intellectual ability

Unscientific behaviour results from failure to apply science knowledge

Scientific thought is the proper yardstick with which to measure the validity of ‘everyday thinking’

**Interactive**

- Science
  - Citizens

Science has problematic boundaries; it cannot answer many questions with certainty

Science is off-centred and integrated with other kinds of knowledge

Science is often seen as inseparable from social and institutional connections

Uptake of science is influenced by trust in the sources and their openness

People make use of science in practical situations and adopt it well to specific everyday situations

‘Everyday thinking’ and ‘knowledge in action’ are more complex and less well understood than ‘scientific thinking’
Science in the British Press
1946 to 1990

number of articles

popular (n=993)  |  quality (n=3008)

papers weighted; n=4001
Figure 2

1946 to 1992

Academic Directors in Physics and Chemistry
Figure 3

1946 to 1992 controversy in 587 articles

Papers weighted, n = 861

% of popular % of quality


0 10 20 30 40 50

% of total articles
LaFollette’s stereotypes of scientists from American magazines

- Wizard
- Expert
- Creator/Destoyer
- Hero
Rosslyn Haynes's cultural stereotypes of scientists drawn from western literature

- the alchemist (deep suspicion of Arabic culture by Europeans)

- the stupid virtuoso (satires of early Fellows of the Royal Society whose behaviour seemed ludicrous)

- the emotionally deficient researcher (classically Mary Shelley's *Frankenstein*)

- the heroic adventurer (perhaps best seen in Jules Verne)

- helpless scientists (who watch pure, value-free pursuit of truth unravel into destructive and immoral exploitation)

- noble idealists (the only really positive category)
**Why and how to bring science to the public**

**Session one**

**An apparently simple story**

The title of these talks seems rather bland and the answers to the implied questions quite straightforward. However, I hope to show that the issues are actually not straightforward nor are there any simple answers.

My title implies that science is something produced by one small group of people, **scientists and technologists**, which then could be (or must be or ought to be?) communicated to a large audience, the **general public** of lay-people who are not professionally involved with science or technology. It seems rather obvious **how** this should be done; by using the conventional methods for addressing such an audience, through the **print and broadcast media**.

Therefore it now only remains to address the question of **why** this general public might wish or need to be informed about science. Here there are several possible answers but they do not present any obvious problem. The UK Royal Society report *The public understanding of science*, published in 1985, under the aegis of the Committee on the Public Understanding of Science (COPUS), gave three principle reasons.

- **An economic reason.** The British economy is not growing as it should because there is a shortage of trained scientific and technological personnel.
- **A democratic reason.** In a society where scientific and technological issues are assuming greater importance, people need to understand science and technology in order to take reasoned decisions on such issues.
- **A cultural reason.** Science is fascinating stuff - it can bring pleasure and insight through an understanding how the world around us works. People who cannot appreciate this are culturally deprived.

These all look entirely laudable. Addressing the issue of bringing science to the public therefore seems simple; the scientific community and media professionals in journalism and broadcasting must try harder to increase the volume of material about science and technology which they can place in newspapers and magazines and in radio and television broadcasts. It is just a question of persuading editors and producers to realise what a wealth of wonderful opportunities science communication presents.

The result should be a better-informed public who can take better democratic decisions about science-related issues, encourage their children to go into science and technology related careers, and who will thank the scientific community for enriching their cultural appreciation of life, the universe and everything.

To an extent there is nothing wrong with this story and there is evidence that the activities supported by COPUS in the UK over the past 10 years may be changing attitudes to science and technology there - or at least have led to many more popular...
scientific books, articles, broadcasts, museum exhibitions, hands-on science centres, science festivals and so on. But the story is too simple. The issues are more complicated and the final outcome of any drive to communicate science to the public likely to be far more ambiguous than an increased public appreciation and support for science.

Even if we accept the simple picture just sketched in, there is at least one obvious complication. The 'why' and 'how' questions may have straightforward answers but the question of what science has not been addressed. Since there is a huge amount of science going on, there must be some selection of what material to report in the media. How is such selection to be made? Who has the power to make it?

The fatal attractions of linear models
There are at least two rather pernicious linear cause and effect models of the relations between fundamental scientific research and the communities in which it is carried out which should be abandoned. One of these has underpinned much policy towards the support of scientific research in most countries since the Second World War. As the model rather flatters science and leads, logically, to a continuation of public funding, it is not surprising that some scientists continue to argue for it strongly.

Here it is argued that technology depends upon scientific knowledge and that economic growth depends on technological innovation. The model is linear with an implied feedback loop to produce a virtuous circle.

<table>
<thead>
<tr>
<th>Fundamental scientific research</th>
<th>new scientific knowledge</th>
<th>technological innovation</th>
<th>industrial application</th>
<th>economic growth</th>
</tr>
</thead>
</table>

some of the economic surplus then ploughed back into more

Analysts have been trying for more than 30 years to find unequivocal empirical support for this model. So far they have failed. The uncomfortable consequence in policy terms has, of course, been for governments to question very carefully their investment in fundamental research.

The basic model of the virtues of science communication in the public understanding of science has the same general form.

<table>
<thead>
<tr>
<th>Fundamental scientific research</th>
<th>new scientific knowledge</th>
<th>popularisation of this new knowledge</th>
<th>general public are fascinated and see the benefits</th>
</tr>
</thead>
</table>

policy decisions informed by
democratic consensus makes
more funding available for

In this model, public mistrust of science or failure by its elected representatives to
vote sufficient funds to its support, is thought to be due to ignorance about science.
Once the public have been properly informed and understand it better they will see
what wonderful stuff it is and persuade their representatives that they should support
more of it. The fancy name for it this the cognitive deficit model. The principle task
of the scientific community and science popularisers here is to fill the empty public
mind with interesting things about science.

It resembles the over-simple educational idea which supposes that children’s’ minds
are empty vessels which just have to be filled with relevant information by
enthusiastic teachers. We know that learning is far more complicated than that. By the
same token, so is the process of informing and changing the behaviour of adult
audiences. While it would be stupid to pretend that telling children things and
informing the public about matters have no effect - there is very little evidence that,
on their own, these techniques are particularly efficient in teaching children or
persuading adults.

Indeed, in so far as more scientific information does influence the public audience it is
as likely to produce negative consequences so far as the scientific community is
concerned. A better-informed public may turn out to be a more critical public. A
genuinely well-informed public might demand that its representatives not only look
very carefully at the total value of resources allocated to fundamental research, but at
how the resources were spent by the scientific community. Surely the logic of better
information in a democracy is an increase in the amount and quality of democratic
decision making.

I think that most basic scientists feel extremely uncomfortable about this, because it
undermines a principle component of their professionalism - that scientists alone are
competent to make decisions about what basic scientific research is done and by
whom. However, I submit that this is a logical outcome of whatever campaign
strategies are used to inform the public. I believe the consequence of using any of
them is to accelerate and intensify the pressure for more democratic control over
science, not an outcome which the Royal Society or COPUS necessarily envisaged
when they set the public understanding ball rolling.

Let us look more closely at the pathways, barriers and gateways of science
communication to find out whether the linear, cognitive deficit model makes sense, or
whether some more sophisticated procedures are necessary to see how science
communication works.

The players in the science communication game
It should be a simple matter to draw up lists of the major participants in the science
communication game. Using the terminology of the market place, these might be
called producers of scientific products of use to consumers. Since moves towards
an understanding of science begin and end for many people while they are still at school, teachers are clearly key players here as well.

**Science producers**
- Research scientists
- Science teachers and lecturers
- Science journalists and writers
- Broadcast producers and editors

**Scientific products**
- Research papers and patents
- Reviews and textbooks
- Popular science books
- Conversations/interviews/presentations
- Newspaper/magazine articles

**Consumers of science**
- Pupils and students
- Scientists and technologists themselves (the professional audience)
- Other professions making use of scientific knowledge (doctors, engineers, technicians, nurses, farmers, civil servants, politicians etc.)
- Lay audiences with special concerns/interests (for instance patients and their relatives, members of special interest or pressure groups, public enquiry participants and so on)
- The general public

**The concept map of science communication**
A valuable new teaching technique has been invented recently, known as the concept map. Students are provided with key terms and definitions used in a piece of science or other conceptual academic work, written out on separate pieces of paper. They then have to assemble these into a diagram, with linking arrows between the terms. They are allowed to write a few words of explanation alongside each connecting arrow, saying how the terms are connected.

Any attempt to generate a concept map using the categories listed above leads to an enormously complex chart. There are very few straight-line, straightforward cause and effect links. Instead we can only produce a dense network of two-way relations. Whatever final version of the chart which we might ultimately agree on, only one thing seems certain - it would not show any linear relationships.

*(an attempt at a concept map)*

**Different professional spheres. Extreme grounds for misunderstanding**
However we assemble the concept map, whatever linking arrows we provide, it is clear that blockages between players are as prominent as gateways. The three main
classes of producer - scientists, teachers and journalists - all speak different languages and have separate codes of professional behaviour.

Turning briefly to the consuming group, they are not a homogeneous ‘general’ public but a massive collection of separate audiences, all interested in different things for different reasons. Some of them share some points of reference and culture with one or more producing groups, but a great many have no overlap with any of the producers. The producers are, regrettably, often profoundly ignorant of the real needs and interests of the groups they are supposedly addressing. Their codes of behaviour do not necessarily take their audiences sufficiently into account (for instance; teachers often do not understand how children learn, journalists do not know who the people are who read their articles, scientists fail to write or speak clearly enough for even an audience of peers to understand what they are driving at).

Under these circumstances it is often amazing that any useful communication of science occurs at all. To highlight some of the barriers to communication, let us focus on the separate professional worlds of journalists, scientists and teachers. This should show that there is a constant need for mediation between them to prevent widespread misunderstanding.

The professional world of the science journalist
Let us start with the world with which we are least familiar, that of the journalist. A key issue here is objective reporting. This must surely be a basic pre-requisite of truthful representation of events? It is certainly a dominant feature of journalistic professionalism. The main characteristics of objectivity are supposedly;
• a position of detachment and neutrality towards the matters being reported,
• a lack of partisanship,
• an attachment to accuracy and other truth criteria and
• a lack of ulterior motive or service to a third party.

However, judgement of objectivity in practice is an unresolved conundrum, especially when values enter into the reporting of facts, which they almost invariably do. Where basic facts are reported, their presentation is supposed to conform to standard truth criteria; they must stand up to independent verification and be consistent when reported by several sources.

There remains considerable doubt about what are the other professional skills of a journalist. The ethos of journalism is much less well defined than that for professions such as law, medicine or accountancy. The prominent media analyst Denis McQuail suggests that;

.....Apart from skills of performance and other artistic or technical accomplishments, the essential media skill is hard to pin down and may variably be presented as an ability to attract attention and arouse interest, assess public taste, be understood or ‘communicate’ well, be liked, ‘know the media business’ or ‘have a nose for news’. None of these seems comparable to the skills, based on recognised and required training, that underlie most other professions.'
Journalists are fundamentally trained to produce news, but it is quite difficult to define what ‘news’ is. One set of descriptive features might be (Park 1940)

- it is about recent or recurrent events,
- it is unsystematic, dealing with discrete events, which it is not the primary task of news to interpret, explain or inter-relate,
- it is perishable, it lasts only so long as events themselves are current,
- events reported are unusual or unexpected, qualities which are more important than ‘real significance’ as judged by their social, political or economic importance,
- news events have ‘news value’ which is always relative and involves subjective judgements about likely audience interest,
- it is mainly for orientation and attention-direction and **not a substitute for knowledge** and
- news is predictable.

This list contains one very loose concept, **news value**, and one paradox, that news, despite being about the unexpected, should be **predictable**. A classic study (Galtung and Ruge 1968) carried out on the selection of foreign news stories by Norwegian newspapers provides some further insight into what these values might be.

- there is a preference for events which fit advance audience expectations (consonance with past news),
- a bias towards what is unexpected and novel within the limits of what is familiar,
- a wish to continue with events already established as newsworthy and a wish for balance among types of news events,
- foreign news interest is influenced by trading partners and international treaty obligations while
- in domestic news, economic and political factors have as much influence as the news values attached to events.

News decision makers (editors acting as gatekeepers) have a set of cultural algorithms about what is a news story and how to tell it. Gatekeeping is the selection of ideas for inclusion. It is subject to convention and ideology because, if it wasn’t, the role of an editor in making rapid decisions would be impossible. Different news organisations consistently respond in a similar way to the same events. They prefer events that fit the following criteria;

- having a short time span (being sudden),
- having great scale and intensity,
- being clear and unambiguous,
- being unexpected,
- being culturally close to the intended public and
- having continuity, being already in the news and consistent with past images and expectations.

News is **predictable** for a variety of fairly obvious reasons, some already implied in the lists of news values above. The presence or absence of personnel and facilities for recording and transmitting events plays a major part in selection. There is a self-fulfilling effect from the location of reporters and equipment in particular places. News is **socially constructed** according to schemes of interpretation and the operating assumptions of news source institutions. They generally scan for information on
specific 'beats'; such as police departments, courts, welfare agencies, government committees and so on. Editorial decisions about what constitutes a 'beat' tend to be unanimous (reflecting common 'news values') and therefore make the type of news presented highly predictable.

This leads to a close symbiotic relationship between media and their sources. This greatly improves the planning of supply, despite the fact that it conflicts with the media's parallel ideology of novelty, spontaneity and creativity.

A great deal of news derives from Public Relations agencies, including those representing science organisations. They are very effective despite the claims by journalists to resist them. In practice, journalists seem very prone to making use of information releases from 'official' sources, conferences and so on, mediated through PR agencies. In fact, it has been claimed that there is a clear bias in their favour. Many PR people are senior ex-journalists supplying information to those working as jobbing reporters, who are often much more junior.

Ideas and information flow through all media organisations in huge volume. There is far more than can effectively be turned into news, useful information or entertainment. Therefore there are selective filters at work at all stages, discarding a great deal and modifying severely what passes through each gate-keeping stage. On the whole, the basis of these complex decision-taking activities has very little to do with conscious understanding or knowledge either the needs of the audience or the requirements of the publishers or owners. The media organisation develops its own ethos, rule of thumb procedures and conventional shortcuts, sometimes summarised as media logic.

The ethos of journalism still revolves round hard or spot news, immediate material which is of the here and now. Explanatory and analytical features need investigation and research. Many media organisations don't have the resources to support these and many reporters, trained in the blow-by-blow hard news school, are temperamentally disinclined to do such work. The credit ethos for journalists also favours the person who 'breaks' the story, rather than one who analyses it. This failure to set things properly in context is a general charge against all media made (with justification) by most radical media analysts.

The organisation, its employees and the play of media logic all conspire to convert a presumably unpredictable universe of events into a predictable temporal, spatial and topic framework. The professional ethos and news values used by media personnel themselves in the processes of choosing, assembling and presenting the news actually prevent readers, listeners and viewers from understanding wider social reality. Even when subject areas and space or time permit the development of analysis, in feature articles and so on, the rigid application of news values prevents proper investigation and explanation.

Journalists themselves still tend to believe that news events drive the process;

events news criteria news reports news interest
(a consequence -
Media theorists, however, see the news interest framework as an overwhelming social construct (a mixture of culture and journalistic feel for news) within which events are noticed and reported.

<table>
<thead>
<tr>
<th>news interest</th>
<th>news criteria</th>
<th>events</th>
<th>news reports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(events are chosen according to socially determined values)</td>
</tr>
</tbody>
</table>

Large media organisations can afford to have journalists specialising in beats such as science, technology, medicine, environment, energy and so on. Within the framework of journalism in general, these science journalists find it quite hard to operate.

For instance, standard space and airtime limitations are harder for them than most, because they feel they need space to explain the complex issues involved, and the culture of hard news does no service to science reporting. It simply is not suitable; scientific material does not fit easily into the news format. Therefore considerable effort goes into trying to make it fit this format, with inevitable distortion of the public perception of sort of activity it is. It comes across as a series of breathless ‘breakthroughs’, many of which turn out to be damp squibs. Science journalists prefer to write explanatory features about science news or (to a lesser extent) to be investigative, although this may imply an antagonism between the reporter and her scientific sources which opposes the need for science journalists to have their sources trust them.

The best news stories also have drama and human interest, again both features mitigating against science reporting. This makes applied science far easier to write about than pure science.

Editors have a huge influence on all reporting. They assign reporters, decide which stories to run and so on. To get copy past their editors, journalists write for their editors and their known prejudices and tastes, rather than for the public who are technically their audience. For science writers there is the additional problem that most editors have no feel for science stories and do not believe the readers are interested. However, audience surveys repeatedly show that editors and readers are not as tuned into each other as the editors like to suppose. Survey after survey shows that people want more science, technology and medicine news.

One obvious problem is that few editors or general reporters have a science background. They therefore find reporting and evaluating difficult. This problem was also common in the first generation of professional science writers in the 1950s/60s who were often general reporters before they specialised. Science specialists are increasingly being recruited from science, but they face a status problem in both their
worlds, scientists may regard them as 'mere' writers (lacking authority in their own right such as is given to political commentators and cultural critics) but also being marginal in the newsroom (the non-science ambience reinforces their role as specialists 'on tap' (like plumbers) rather than central to the news operation.

In theory, journalists from different papers are in competition with each other to find and report stories (scoops) which their rivals do not carry. While this happens less often than is supposed, it does form part of the normative ethos of many reporters.

However, this was not true of the 'inner club' of science specialists working for the wire services and the quality daily press in the USA from the 1960s to the 1980s. They formed a co-operative, not a competitive group. The origins of this lay in their accidental assignment from the general reporting pool to cover space technology in the 1960s. They were not science specialists, but they all went to the same big events such as satellite launches and spent many weeks away from the office. They formed a group for mutual support and self-help in a new environment where they did not know very much.

Such a scientific cartel undoubtedly helps journalists produce good, accurate stories against tight deadlines but operates at the expense of the public. There are no objective criteria over news value and the topics covered tend to be narrow and gee-whizzy rather than broad and socio-political.

**The professional world of the scientist**

It is thus clear that the professional and ethical framework within which journalists operate is complex, that the interests of the audiences they are supposed to serve are not always central to them and that science journalism sits uneasily within this matrix. In passing we have also seen that the journalistic framework is very different from that of science and that therefore representing science in the media to the satisfaction of both groups presents difficulties. I will not describe the professional framework of scientists since would seem rather pointless in front of this audience. However, it is only sensible to point out that there are similar contradictions and tensions about the conduct of science and its professional and popular communication of which scientists are sometimes not overtly aware.

This is also a highly contentious area, given the work of sociologists of science over the past 30 years, and their claims that scientific interpretations of how nature works depend as much (if not more) upon social negotiations between individuals and groups within the scientific community as upon the weight of experimental or observational evidence in favour of these interpretations. Some scientists are clearly very upset about this idea and its implications, although others seem pretty laid-back about it, at least in its tepid rather than extreme form. I don't intend to make any contribution to this dispute here, except to say that any student of communication and education is bound to be impressed by the extent to which ideas are originated, developed and learned through the medium of language and therefore be forced to accept sceptical structural and post-structural philosophical arguments about the lack of any firm anchorage points in the use and meaning of this language.
I therefore have considerable sympathy with the general notion that scientific knowledge is socially constructed while not wishing to deny that the interpretations agreed on must be compatible with some of the evidence about how the world ‘out there’ actually seems to behave. If one accepts a degree of social construction (or at least negotiation) in the practice of science then one can see that the notion that the conduct and direction of science is only the business of scientists cannot be sustained.

The professional world of the science teacher
Since the introduction of the National Curriculum in the UK, with science as one of its core subjects, all children now learn some science at every stage of their school careers to age 16+. We no longer have the situation where many British primary schools did not do any science, nor need pupils narrow the range of subjects they study at the age of 13 or 14, such that they often give up science at that point.

Most science teachers probably hope that at least some of their pupils will continue in science after they leave school and go into professional scientific careers. Most secondary science teachers have themselves gone part way through this post-school training and share many of the values and attitudes of scientists. Despite the weighting of the whole school education system towards the specialist needs of this small pre-professional group, a large body of research evidence indicates that even science-enthusiast students are failing to learn the concepts considered essential for intellectual competence as scientists.

We would surely all agree that a major objective of science education must be to teach currently correct scientific concepts and information. But research study after research study shows that deep-seated and persistent misunderstanding of scientific principles occurs at all levels of science education - from children to undergraduates, postgraduates to professional scientists, teachers and engineers.

One general interpretation of this apparently sorry state of affairs is the persistence of ‘pre-schooled’, common-sense interpretations of events, even among those subjected to a lengthy scientific education. Educationalists of the so-called constructivist school might see this as a teaching failure; these students have not reconstructed their own interpretations of everyday events in the light of the scientific concepts they have learned.

It also seems essential for science students to have a sound grasp of the operational processes of science - in other words how to investigate problems scientifically; how to interpret results and how to present them.

There is increasing evidence of pupil confusion in this area as well. The reasons why experiments are conducted are not understood; the open-ended nature of genuine experiment is not grasped; the interpretative relations between results and the problem under investigation are not understood; and results presented in tables or graphs simply do not mean anything to those who produced them. Reports of investigations reveal that the writers often have no idea why their results mean anything and, even if they do, they cannot explain why to third parties. It seems that pupils are very unsure
why they are doing the practical work and what interpretations they are supposed to make.

Trying to explain why pupils' expectations from practical investigation are so different from those of teachers is difficult. One plausible explanation is provided by work done at the University of York, led by Richard Gott. Their explanation is that children, until at least the age of 14, always think within a concrete engineering or technology framework and make use of data sparingly. Their teachers, on the other hand, operate within a science framework, constantly stressing the search for underlying abstract relationships and using these to make predictions. It is not, therefore, surprising that teachers and pupils often do not understand each other, nor that in later life when they are adults, these former pupils do not understand the content, methods or purpose of scientific research.

When young children do investigations, they often draw graphs and some data processing. However, they usually ignore this when they draw conclusions. By the time they are at the end of their primary education at age 11 they have become quite good at using data to draw conclusions. They seem to have understood the basic day-to-day processes by which science investigation is done. However, by the age of 16 they have regressed and cannot draw conclusions from data. They collect it, they draw graphs from it but they do not think about it nor use it to draw conclusions. They don’t really understand the point or value of empirical evidence at all.

Work with non-science undergraduates produces much the same results. Given a problem, they will happily do investigations and generate data, but cannot understand how the empirical work they have done has any bearing on the problem. They simply cannot plot or interpret graphs of the relationships between variables. Anecdotal evidence suggests that science graduates are probably no better. Industrial employers in the science/technology sector constantly complain that science graduates lack investigative scientific skills. They are over-ambitious and plan complex exercises with little idea of how to control variables. They do not understand the basics of experimental investigation nor the mechanics of hypothetico-deductive thinking.

Science students are seldom introduced to the idea that solving a problem in a laboratory is one thing; applying the solution on a far larger scale in plant, factory or office is quite another. Many fully-trained scientists are incapable of understanding that the conditions outside a laboratory are entirely different from those within it. Many scientifically educated graduates are therefore ill-equipped for development work, which is where the great majority of employment opportunities in research lie.

Science and technology issues in the real worlds of politics and employment are increasingly under-determined; there are many misunderstood or poorly defined parameters. The scientific data may actually be 'softer' than the 'hard' political decisions which have to be taken - classically on environmental issues, for instance leukaemia clusters round Sellafield, CFCs and the ozone layer and so on. But we still teach science in schools as if the answer under controlled and precise conditions will do for the wider world outside.
Under-determined technological controversies nearly always involve overt value-judgements. Science studies over the past 30 years has shown that covert value-judgements are also characteristic of scientific decisions. Work on pupils’ understanding of science suggests that few understand these social dimensions. Most believe that technical controversies are always resolved by simple evaluation of the facts which will lead logically to a single solution. If that is not possible, pupils simply call for more facts.

However, most real world issues have to solved quickly, with the information to hand - there is no time for the accumulation of more facts. In any case, such additional information will not necessarily help the situation, because the solution is not dependent only on scientific or technical information.

The kind of scientific information which citizens actually find useful for solving their real-life problems is seldom available. Time and time again research shows that people’s problems are formulated in ways which traditional academic science finds hard to answer. Intense negotiation is often needed before academic knowledge can be made useful for patients, people with disabilities, people at planning enquiries and so on. The mediation needed is often so intense, it suggests that academic science is simply exploring the wrong issues as far as problems of direct interest to the public are concerned.

For instance, when academic scientists from Bristol University went out to talk to shoppers about their work in a ‘boffins meet the people’ exercise in a local shopping centre, they were startled by the nature of the problems which people had. It caused one or two of them to think seriously about the direction of their own work and the general benefit which they always assumed it had.

Conclusions
At this stage only tentative. All I have tried to do is suggest that the worlds of the players in the science communication game are very complicated and that meaningful scientific information in one professional context may be useless in another. Above all, we have now firmly introduced the idea that science for a school pupil or a member of an adult public audience may have to be framed entirely differently from its professional format before it becomes meaningful or useful.

The problem might be more serious than that. Some radicals argue that this mismatch between what professional scientists produce and what various public audiences need means that we are producing the wrong kind of science. The logical conclusion of a close analysis of science communication may be that it is scientists, not the public, who need to learn more.
Why and how to bring science to the public

Session two

Introduction and resume
In the last lecture I spent some time looking at the different professional worlds of science journalists, scientists and science teachers, noting that although there are shared elements in the frameworks within which they operate there are also large differences and that these may interfere with smooth communication between them. Once we begin to factor in the effects of these communicators on their audiences, the situation rapidly becomes more complicated.

I gave more that a hint that the various publics, both student and adult, do not necessarily find the science which they are offered by the scientific establishment either useful or interesting. I also suggested that the real problem for the public understanding debate may not be centred entirely on a scientifically ignorant public but also on a lack of insight on the part of scientists of the public context of their work. I would now like to explore this question of a dialogue between scientists and their various audiences further.

Such a dialogue may involve consulting people whose knowledge of the issues is poor and who do not know what they really want. It is often too easy to dismiss what they are saying as irrelevant. For instance, market researchers trying to judge how a hypothetical product will play in the market-place often make completely wrong decisions because the public are commenting in ignorance about issues upon which they rapidly change their minds when the product moves from hypothesis to reality. Educationalists now make a habit of consulting both students and employers about what they need or want from the education system. The results of such consultations are often bizarre because neither students nor employers actually have very clear ideas of what they do want it to provide. Nevertheless, it would be silly to stop asking. The answers may not be immediately relevant but they constitute a powerful resource in understanding misconceptions and background information on how the worlds of producers and consumers of scientific information may be better harmonised.

Some of what follows may seem pretty remote from the world of fundamental science. I am going to talk about such issues as patients understanding their diseases, neighbours of chemical plants understanding the risks they may run in the event of an accident, local councillors taking decisions on land-fill waste sites in the light of information about methane generation. But I suggest to you that these are the kinds of practical everyday and mundane issues where most members of the public find themselves needing to understand science.

The current public understanding of science debate in context
The current concern with the Public Understanding of Science dates from 1985 and the Royal Society report, The public understanding of science. Similar debates have
occurred at least twice before in the UK. During the 1830s, as the industrial revolution accelerated, there was great concern about the inadequate training and education of the workforce for new factories. One hundred years later, in the 1930s, there was another outburst as left-wing politicians wondered whether the workings of the capitalist economy were preventing the successful exploitation of scientific advances.

All three of these debates have been framed in terms of the interests and attitudes of science and scientists. The scientific establishment uncovered what they saw as a deep ignorance on the part of the public of scientific facts. The obvious solution arrived at in each case was for scientists to spend more time and energy informing and educating the public about what they (the scientists) know and do. The public understanding agenda is always set using an overtly ‘deficit’ model of communication; the public do not know very much; and the scientific community will overcome this ignorance by telling them about science. Public understanding has seldom been seen as a two-way process where existing public knowledge and attitudes are taken into account, and where scientists themselves might be expected to learn something from (and about) the public.

Research has shown repeatedly that communication of scientific or technical information to the general public or, more importantly heterogeneous subsections of it, using the one-way, cognitive deficit model seldom works. For instance, the sociologist Alan Irwin has demonstrated that communication to at-risk public groups about industrial of other hazards and how to proceed in an emergency is extremely poor. The information is not couched in terms to which the target audience can relate or from which it can learn. Such information should be set within the cultural and practical framework of the audience, not of the interests and concerns of the scientific, technological and corporate communities. In the parallel case of biomedical information provided by doctors to patients, time and again it is shown that the patients find little of value in what they are told by doctors. They learn much more valuable and helpful things about their disease and its treatment from the experiences of other patients, or from lay carers such as the parents of sick children.

There are several conclusions which one might draw from this. The practical one is simply that any professional group with a technical message needs to understand in some depth the cultural milieu of the target audience and tailor the presentation and content of the message to the characteristics of that audience. On the whole, despite the wealth of commercial expertise and academic analysis of marketing and advertising, this is seldom done.

One might also draw a more political conclusion. Several sociologists argue that the whole public understanding debate is simply a diversion, a ploy to make the public responsible for failures which are actually caused by administrative and political ineptitude within the institutions of science itself (essentially its failure to secure enough financial and popular support for continued high level scientific research activity). Radicals suggest that the real problem may be that science and technology objectives and achievements have become divorced from the everyday lives of the people whose taxes pay for much of it. A policy of science designed only in the interests of the scientific community, of government, or of corporations may not be
satisfactory. Perhaps the direction and purposes of science need to change in response to democratic demands?

Perhaps scientists need to learn more about what the public perceives to be important scientific and technical problems, and to try and address these more directly than they do at present. Perhaps it would be possible to evolve a system in which members of the public could contribute to debate about science and technology policy through some extended form of peer review.

**Science-in-general and science-in-particular**
The sociologist Mike Michael distinguishes between what he calls ‘science-in-general’, which is official, reified, textbook science; reliable knowledge acquired by specialist practitioners, and ‘science-in-particular’; defined as bits of science of practical value and use in everyday circumstances. Science in the first case is positivist, authoritative, objective and isolated from the distorting influence of practical problems and everyday behaviour, while in the second case, knowledge is used by ordinary people in the conduct of their lives.

Most people think of ‘official’ science as remote from their concerns and exclusive. However, people are not ignorant of what kind of thing it is or of its values and purpose. Many can articulate quite sophisticated analyses of what is scientific and what is not. However, at the local level of using scientific information in everyday life, ‘science-in-particular’, the mystique of science must be broken and the science made mundane and directly relevant to the problem in hand.

In one of his surveys, Michael interviewed people who had volunteered to measure the amount of radon in their houses to find out why they had volunteered to undertake this task for six months. They were all local council employees and their reasons for taking part were only vaguely to do with ‘science-in-general’; advancing abstract, scientific knowledge about a possible health hazard. It had much more to do with their local, employment relationship with the Council which had called for volunteers. Measuring radon in your home is a piece of ‘science-in-particular’ and the motivation to take part is embedded in local culture rather than deriving from the knowledge-generating culture of ‘science-in-general’.

A team led by the educationalist Professor David Layton carried out a series of case studies in and around Leeds which demonstrated clearly the distinction between the textbook science agenda of professionals and the ‘science-in-particular’ approach of lay groups. They undertook four case studies; two of which were on the parents of Down’s Syndrome children and the deliberations of a local authority waste management committee dealing with methane leakage from an infill site.

**Dealing with Down’s Syndrome**
Down’s Syndrome is a relatively rare disease caused by faulty chromosome inheritance. Sufferers have three copies of chromosome 21, rather than the conventional two copies which the rest of us have. A considerable amount is known about the origin, reproductive risks and distribution of the syndrome in the population.
Patients usually have a common pattern of minor anatomical and morphological abnormalities but the key problem for sufferers is that they have learning difficulties of varying degrees of severity but in the worst cases the prognosis for intellectual development is very poor indeed.

The medical establishment, in 'science-in-general' mode, can and does tell people, in some detail, about the chromosomal origin of the disorder. As far as most parents are concerned this is irrelevant because it has absolutely no bearing on the practical problems of caring for a Down's child which they face. Insider science - science driven by curiosity about the natural world and in generalised understanding - is of no use to them. They need immediate, short-term information on clinical, social and other aspects of the condition in their particular local setting. Not only may this be hard to come by, but parents often cannot articulate what they need to know in the early stages.

Eventually most of them are able to cope satisfactorily with the situation, although they are often dismissive of the negative attitudes towards 'severe' disability shown by both medical professionals and ordinary people. The medical picture of the disease generalises a great range of variation in symptoms and experience into a simple overview which classifies this disease as a severe disability. For a variety of complex reasons, in this case the medical classification has become embedded easily in popular culture, and ordinary people tend to shun Down's patients. But to the parents of an individual patient that is just what she is - an individual. Other aspects of her existence, personality and social relationships are just as important as the specific disability from which she suffers. The parents simply do not recognise the clinical shorthand pigeon-hole into which their child has been placed.

Care regimes adopted by parents vary enormously but the main problems revolve around development (mental and physical) feeding, diet and digestion. One might suppose that scientific knowledge of the human anatomy and physiology would help here but there is little evidence that it does. Many people devised good care methods using common-sense built on their increasing practical experience of the condition without any grasp of science or very much clinical or social advice. Where therapies of procedures were recommended as a result of scientific medical investigations, according to Layton parents often complained that 'professional science could not provide .. a clear answer to the question of the efficacy of the treatment.'

Nor is an understanding of reproductive physiology of much use in managing the emergent sexuality of adolescent and young adult Down's individuals. Scientific understanding of speech does not aid their communication problems either, although the services of a good speech therapist are often valuable, although very hard to obtain. Few parents received anything positive from their contacts with the medical profession. Genetic counselling received a mixed response. The advice on possible recurrence was too statistical to be digested, most simply appreciated the availability of amniocentesis to check the status of the next foetus. Most felt the need to try for another child (or children) fairly quickly to ensure that the family were bunched.
Ancillary professions such as health visitors, speech therapists, physiotherapists and social workers had very patchy effects, most not knowing enough about Down’s Syndrome specifically to be of very much help. However, almost without exception, self-help groups were extremely valuable. As we have already suggested, the specialist audiences themselves are the best ones to work out what they need and how to get it. A clear implication for effective science and medicine communication is to provide financial and other help to enable such self-help groups to communicate effectively by reaching more people in their target audience groups.

Parents could or did not make any use of what scientific and medical knowledge was available which might help them and the professionals failed to learn anything from the parents which could have redirected their research or their attitudes towards treatment in a direction which has greater practical value for the patients and their relatives. Clinical consideration of the disease remained locked into a scientific framework (probably without consciously realising it) which refused to take seriously the messages coming from the most important audience for their work and its communication, the patients themselves.

Managing methane from waste infill sites
Disposal of domestic and industrial waste by landfill was a common practice in Great Britain in the 1970s and 80s. Quarries, mines and other ‘holes-in-the-ground’ were filled with rubbish and then planted and landscaped. In some cases housing or offices were built on or near this reclaimed land. Little notice was taken of the potential for bacteria in the landfill to digest waste and produce large volumes of methane gas. This can seep out of the site, sometimes at air-explosive concentrations (5-15% mixture with air). American investigations discovered this problem in the mid-1970s but in the UK the dangers were not recognised until the late 1980s. And this despite the well-known dangers of methane, from mining and tunnelling explosions, and the common knowledge that it is generated from biological decay (as marsh-gas in ponds, for instance). But knowledge is compartmentalised. Landfill dangers were not foreseen.

Landfill methane leakage is dealt with by local government. The problems are considered to be technical, engineering problems which are dealt with by council employed engineers. Subcommittees of the elected council (the democratic representatives of the local population and the employers of the engineers) often have only an overseeing role. They are advised about technical action, usually approving essential work and voting the necessary funds to carry it out. However, on some occasions, technical issues have much wider implications and the councillors become involved. The councillors on a Waste Management Subcommittee in a northern city were told by their voters and their engineers about severe problems with methane leakage from a landfill site with new housing situated nearby. The engineering solution proposed to the problem was to duct the gas to a generator to produce electricity. However, this was noisy enough to provoke protests from local residents. Technical ‘fixes’ were generating conflicts of interest as they were applied in social and political context.

Following these problems, the Sub-committee decided to try to prevent the issue of another landfill licence for more waste disposal. They lost the battle. The national
Department of the Environment decided it should go ahead. The elected councillors responded by imposing draconian conditions on the site developers. The developers appealed at law against these restrictions and at the time that Layton's team wrote up their results this case was still undecided. Councillors did not leave this issue to be settled by their engineers. They took a direct interest because of previous problems with landfill sites.

Most councillors knew that methane could form an explosive mixture with air, but otherwise their knowledge of its behaviour was sketchy or just plain wrong. The composition, density, smell and toxicity were only vaguely grasped at best, migration through the tip was seen as analogous to fluid flow through channels rather than diffusion across the whole tip, and there was virtually no understanding of the science or technology of the generators used to make electricity from the gas. They clearly relied very heavily for information and advice on their engineers. They received some optimistic messages from them about the benefits of solving the problem with a methane-powered electricity generator and the suitability of the sites for landscaping, once the landfill was complete. The political situation was forcing councillors to feel confident enough about the technical issues here, but their need to understand was limited by the particular context of the decisions they had to take. According to Layton:

'Councillors were struggling to develop their understanding of 'methane' by drawing upon elements of vicarious experience which, in conventional scientific terms, might have been judged irrelevant to solving the problems posed by the migration of landfill gas. This developing understanding was anchored in the particular context of the issue facing them as councillors and, in some significant respects, not merely different from, but richer and more appropriate than the conventional scientific account of methane and its properties. For the councillors, the 'self-standing' scientific knowledge of methane made sense, and became useful, only when it was integrated with other components of their experience and judgement.'

The advice of the technical officers was important. The councillors had to rely on it as a base of technically correct data upon which to make judgements. With the new licence, the councillors over-ruled their officers, who claimed the new site and the proposed methane busting solution posed acceptable risks. The councillors, sensitive to political and other issues, found reasons for not accepting their advice, such as the history of technical decisions which had proved to be wrong in the past.

**Understanding and using science in the public domain**

What lessons should be drawn from these examples of scientific and technical issues of very direct concern to subsections of the public audience?

Public understanding survey work has revealed citizens ignorant of basic scientific facts. This has spawned the cognitive deficit model, which tries to solve the problem by having more scientific experts pushing scientific information at passive customers.
These case-studies refute this model. Scientific knowledge is not reliable in public contexts and the customers have to actively engage with it before it is any use to them in their specific contexts. To quote Layton again

'...lay recipients of scientific knowledge were far from passive: they interacted with the science, testing it against personal experience, contextualising it by overlaying it with particular local knowledge and evaluating its social and institutional origins.'

The whole emphasis of science in the public domain is that it often seems incapable of giving a single right answer, whereas the supposed strength of science, is that it does provide unequivocal right answers. Such rhetorical claims simply do not stand up outside the laboratory. Pasteur's claim to 'give me a laboratory and I will move the world', cannot be universally substantiated.

Abstract principles (science-in-general) do not turn out to be principles which, once mastered, have merely to be effortlessly 'applied' in practical situations (science-in-particular). Lay people have to use it as a quarry of information and expertise, often quite peripheral to their main concerns, to help them solve problems. They construct a 'practical knowledge' which is embedded in the particular social context in which their problem arises.

**Constructing the cultural context of science**

We have already seen elements of the cultural image of science-in-general, the science that scientists produce and which fills the textbooks. It is seen as authoritative, objective and reliable in its laboratory context - largely because of the detachment of that context from the messy influences of wider social and cultural influences.

Surveys suggest that scientists and engineers themselves are still trusted and respected by the public for their knowledge and integrity. Newspapers still call on scientists for quotes about a wide range of issues and it is clear that they do this because science still has substantial authority. Scientists are experts within their abstract and remote domains.

To an extent this image is being undermined by the failures (as perceived by segments of the public) of science-in-particular. But this is not happening as much as one might think. Michael's survey work showed that people can draw a clear distinction between science of the textbooks (which they do trust and believe - because they trust scientists as competent professionals, not because they understand the science themselves) and the local situations where the application of this science - or even its basic relevance - are seen as problematic. However, even if science-in-general is seen as sound and reliable, scientists and their knowledge are not looked at entirely dispassionately or considered only on their intrinsic merits. People bring to their analysis of science a large amount of cultural pre-conception. These pre-conceptions are drawn from a wide range of sources, many of which are fictional and mythological. Scientist-figures within these myths and fictions often fulfil roles which have little to do with their behaviour as scientists. Yet they proved powerful cultural stereotypes and it is very hard to shake them off.
Furthermore, these stereotypes change over time and in different places. We can track the existence and transitions of popular attitudes to science by examining how cultural products - books, films, newspapers and so on - represent science. Here we are looking at them not as a means of promulgating science and scientific ideas but as reflections of popular attitudes towards science. A number of studies have been carried out on the imagery of science and scientists and we will look at a few of them here.

**Science coverage in the British Press**
There have been very few long-term studies of science coverage in any of the mass media. Probably the most comprehensive so far is an analysis (by Martin Bauer's team) of newspaper coverage of science and technology in the Britain between 1946 and 1990.

This study found a clear pattern of cycles of coverage (figure 1). The coverage in the quality (broadsheet) press shows a series of four peaks, which seem to correspond to coverage of four successive developments; nuclear power (late 1950s and early 60s), space (late 1960s and early 1970s), information technology (late 1970s and early 1980s) and biotechnology (late 1980s). These were the key technological issues for public debate in these periods.

There is evidence of a change in attitude towards science over this time-frame. There was an initial phase when the tone of coverage was positive and celebratory (1950-1965) and a second phase in which coverage became increasingly negative and critical (1965-1990). This correlates reasonably closely with a transition from an early emphasis on the potential benefits of science and technology, with little concern for possible risks, to one where the risks were given much more prominence than benefits, a transition which occurred quite sharply in the 1960s. What caused this change in cultural attitude from optimistic to pessimistic is still unclear.

The kind of science covered in the newspapers has also changed over time (figure 2). Until the mid-1960s there was a clear dominance by physical science (more than 50% of articles), but physical science coverage has been falling steadily since then, giving way to a combination of social/human and bio-medical sciences (between them occupying 60% of space in the late 1980s). Evidence collected by other methods suggests that the swing from physical science and technology towards health and medical issues has been more marked than these data suggest.

It is often claimed that the major factor encouraging the coverage of science and technology in the press is controversy. This historical series does not support this contention (figure 3). In general only about 25% of articles are concerned with controversy, although there are two sharp peaks in the quality press in the late 1940s and the 1980s (with a parallel peak here in the popular newspapers). The first is probably concerned with atomic weapons and alternative peaceful uses for atomic physics, the second, biotechnology and genetic engineering.

The most extensive recent detailed content analysis of British mass media was carried out by Anders Hansen and Roger Dickinson on samples of press and broadcast output
in April and May of 1989. Figures 6, 7 and 8 show the results for newspapers, television and radio. The dominance of bio-medical and social science coverage revealed by Bauer et. al. is confirmed and reinforced. The top four categories of newspaper coverage all fit within this framework and constitute 70% of the total, they are four of the five top television categories at 68% of the total, and top four on radio at 71% of the total.

One of the most interesting conclusions from Hansen’s various surveys is that 50% of all the portrayals of science are in articles not specifically about science. The main subject area was perhaps crime, politics or moral and ethical issues. Previous surveys have not paid enough attention to this, looking only at those articles which had a dominant science-base as judged by their headlines. This resonates with the work on science-in-particular. Much science becomes almost casually embedded in everyday political, social, medical or environmental issues. The interest in, and use made of, that science is driven by these social contexts, not by anything intrinsic in the progress of science itself.

Cultural stereotypes of science and scientists
A pioneering study here was carried out by LaFollette. She explored the variety of stereotypes of scientists which emerge from an analysis of popular writing about science in American magazines from 1910 until the mid-1950s. These stereotypes were not static, they shifted over time. The cardboard cut-outs changed.

However, certain characteristics of scientists were similar in stories drawn from across the whole period. The key features were the supposed personality and physical traits of scientists; the possession of a unique ‘genius’, dogged persistence, foresight, detachment and modesty. Only the eyes seem to change, from all-seeing clarity before 1945 to a certain wary cloudiness after the advent of the bomb.

LaFollette explores the variations within the stereotype, recognising characters labelled wizard, expert, creator/destroyer and hero. She writes that

‘Each of these stereotypes characterised scientists as somehow distinguishable from ordinary people. ..... When the scientists were described as wizards, they seemed mysteriously clever, possessing secret knowledge and holding considerable power over nature. As experts they knew all and could be asked to share their knowledge with society. As creators and destroyers, they bore responsibility, both positive and negative, for the end results of their knowledge. As heroes they combined an optimistic belief in a better future with insatiable curiosity, restlessness, a drive to explore, and the ability to explore new paths.’

Roslynn Haynes has recently published a book-length analysis of the images of scientists in western literature. She follows most previous analysts in noting that the literary image of scientists is at best poor, at worst, positively evil. She traces these images back and, like LaFollette, identifies a group of stereotypes;
- the alchemist (deep suspicion of Arab culture by Europeans),
- the stupid virtuoso (originating in satires of early Fellows of the Royal Society, whose activities seemed to the general public to be ludicrous),
• emotionally deficient researchers (classically Mary Shelley's *Frankenstein*),
• heroic adventurers (for instance, as found in Jules Verne),
• helpless scientists, who watch the pure, value-free pursuit of truth unravel into destructive and immoral exploitation.
• noble idealists (the only really positive category)

Steven Goldman has looked at the image of the engineer in popular American films. Like Haynes in literature, he sees a predominantly negative image of science and technology in this more popular cultural form. He points up the contrast between this negative image and American pride in technological ingenuity and the massive public funding for science and technology over the past 40 years. He explains it by positing that the films concentrate on engineers as pawns of corporations and public institutions, not heroes helping to bend nature to beneficial social aims, which he believes summed up the image of the engineer in earlier films of the silent era.

The bad news here is that clearly most of these cultural stereotypes are either negative or portray scientists as other-worldly and emotionally detached. But the better news is that attitudes towards science and technology quite clearly can and do change over time.

**Conclusions**

I am conscious that what has been said in these two lectures has been a hotch-potch of themes which do not hang together well and from which it is difficult to draw clear, practical lessons about communication between the scientific and various lay communities. I said at the outset that one of my objectives was to show that the issues were not straightforward and that there were no simple answers. I hope I have succeeded in these essentially simple tasks. But clearly I must make some attempt to draw these threads together and say something about the specific scientific concern of this organisation - particle physics.

As we have seen, the amount of coverage given to matters to do with physics, in British newspapers at least, is now very small. We are also in a cultural period of general dislike of science and scientists, which is compounded for the particle physics community by its association with nuclear weapons and nuclear power. I have not looked at this specifically here but it seems clear that particle physics has been a major victim of the cultural transition in the 1960s from technological optimism to pessimism, a transition which I suggested was not well understood.

However, there seems little doubt that the political, military and social histories of nuclear weapons and nuclear power generation (science-in-particular applications of fundamental science) were themselves major influences on that cultural change. Spencer Weart has written well about this and the problem is encapsulated in the title of his book on this theme, *Nuclear Fear*. Most people now associate the word 'nuclear' with unease and disquiet. The word has acquired a thick patina of unpleasant associations which it is now incapable of shaking off. Culturally, no-one will write nor anyone read about 'nuclear' matters unless they are couched in the current cultural stereotype of fear and loathing.
It is very hard for the particle physics community to do much about this on its own. Any positive messages which it tries to give out are simply ignored or mistrusted because they go against the stereotype. Engineering a cultural change of optimism towards this branch of science is complicated and no-one knows how to do it. However, the fact that atomic and nuclear matters once fascinated public and politicians alike means that there is no reason why it could not happen again. That might be a cause for optimism although it is somewhat depressing to feel that there is little the community can do which will determine when and where the cultural change might occur.

Some sections of the public are certainly very interested in a number of science-in-general themes and they probably always have been. Publishers simply seem more aware of this and are prepared to commission popular books on scientific themes more readily than they were even five years ago. Indeed, it is something of a golden age for popular book publishing. Again, the reasons for this are complicated and little understood but from the practical point of view of commissioning editors it is clear that the best-sellers all centre round themes of long and continuous human cultural curiosity; what is the origin of the universe and where did we humans come from. Most best sellers are therefore about cosmology or human evolution. Clearly, some particle physics work has a great deal to do with cosmological speculation. That seems to be the only promising area to catch wide public attention to particle physics.

I have also argued that a powerful cultural determinant of public attitudes towards science is the science education they received as children. Not surprisingly, I believe the best chance of doing any serious cultural re-engineering and changing social attitudes is probably most likely to be achieved by looking hard at what science education is all about. I fear that in the UK, despite the National Curriculum and science for all until the age of 16, the net effect may be to cause more adults to lose interest than to gain it. As we currently have it, the science we teach in the UK is not especially useful or vocational and nor is it seen in a context or with a vision which is likely to inspire much interest outside the small group who find it deeply satisfying anyway.

What I would stress again is that the science education system, certainly in the UK and probably elsewhere, is failing to produce people who have any grasp of more complex types of physics at all. Fundamental misconceptions about most areas of physics are especially widespread, even among physics graduates. Whether that is important and how to correct it if it is are matters about which I admit to being confused.

But I will end with a suggestion that none of these public understanding problems may matter anyway. The public understanding model relies on the idea that more science communication will lead to more science appreciation which will lead to more funding and support - the linear model, with feedback, of science communication. I don’t believe this model reflects reality at all, therefore lack of public interest in particle physics may not be a problem. Indeed, one might argue that the continued support on a pretty massive scale for particle physics is strong evidence against the linear model, given the cultural distaste for the terms ‘atomic’ and ‘nuclear.’
But these are all superficial thoughts. I must leave it to you to decide whether anything I have said is useful and what lessons you might want to draw from it for science communication efforts in particle physics.

Nicholas Russell
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