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(1999) shows how this iconic techno-scientific innovator employed a range of genres and played a variety of roles. Secord's astonishing reconstruction of the response to one Victorian bestseller (2000) is perhaps the most detailed account we have of the audience for popular science in any period. These studies, and the studies of Victorian popularization introduced by Cooter and Pumphrey (1994), suggest how much there is to learn about the complex embedding of popular science texts in our own culture.

formed in everyday practices: the way a quoted speaker is introduced, a metaphor used instead of a technical term, a table summarized and simplified. If we as discourse analysts take the boundaries as given and obvious at the outset, in our selection of texts, or of analytical tools, or of categories of social explanation, we miss this work, and attribute authority as an essential aspect of science, rather than as an achievement.

A note on further reading

I have noted that different lines of research on popular science texts have different aims. For policymakers these analyses may identify problems and contribute to the promotion of scientific institutions. For applied linguists they may assist in teaching scientists who are learning a new language, or in technical translation. For rhetoricians and science communication scholars they may help make scientists' writing more effective. For cultural studies researchers they are one aspect of wider cultural change in gender, class relations, or relations to nature. For historians they are one way of seeing science in a wider public culture. Discourse analysts need to consider work in all these strands. (I think it is particularly unwise to seek out only the strands that support one's own view of the authority of science in public debate, since significant work has been done by both promoters and critics of science, and the two sides are not always as distinct as they may seem in the 'Science Wars').

Fortunately there are several recent works that will serve as a good introduction to these different strands. Gregory and Miller (1998) is an excellent overview in English that covers both science studies and media studies perspectives, and gives useful examples. The review articles by Lewenstein (1995b) and Wynne (1995) are still useful. But I find the historical studies provide the most provocative and broad views of scientific texts in public culture. Bazerman's study of Edison

authority is at issue, the interaction is not a simple matter of the public examining the credentials of the expert to see if he or she is qualified to speak on a topic; it involves the active construction of believable or discreditable identities, and alignments that might shift in the course of one interaction (Hamilton 1998; Hinchliffe 1996; Myers and Macnaghten 1998; Myers forthcoming). The failure of scientists to recognise these interactions, and the subtlety and complexity that discourse researchers have shown in them, may account for some of their exasperation when their messages (on the need for a supercollider, the applications of sociobiology, or the risks of nuclear power) do not have the desired effect.

Boundary work

One could argue for the maintenance of each of the boundaries I have described and questioned around popular science texts. One could reasonably insist that there is a place for expertise, genres of carefully examined claims, science as a distinctive discourse, words (and mathematics) as privileged instruments of rational argument, and information stripped of personal interaction. But for most of the issues in which popularization matters, such a carefully bounded, single-minded, and authoritative science is not possible. We cannot understand why there are tensions about genetically-modified organisms, vaccinations, or climate change if we assume that science is distinct from the rest of culture, and that the public is, on scientific matters, a blank slate.

Maintaining such boundaries takes work. That is the claim made by Thomas Gieryn in a classic article (1983), in which he traces the emergence of disciplines and debates about authority in the late nineteenth and early twentieth centuries. Such divisions between science and non-science, professional and non-professional, divisions that we take for granted, were formed in historical struggles, and are re-

images as examples in most academic journals. And it reminds us that texts are irreducibly material: words are essentially the same in a new font or on poorer quality paper, but the glossy picture, or the museum exhibit, or the lecture performance is likely to miss something when reproduced on the page.

Information and interaction

The dominant model of popularization assumes that the aim of the process is to convey scientific knowledge to a wider audience. As we have seen, some studies measure the process by checking to see whether members of the public know certain facts; if they don't, they don't know science (for a critique of such studies, see Wynne 1995). Some scientific institutions also assume that if people knew more about science, their attitudes towards the authority of science in matters of public policy would change: they would be more likely to believe estimates of the risk or safety of nuclear power plants, vaccinations, or skin cancer. But this is clearly not the case; people assess messages about risk in terms of such factors as their trust in the person or institution telling them, its past record, their memory of other, similar issues, their feelings about how this issue fits with their own experience (Wynne 1996b; Wynne 2001).

Popularization is a matter of interaction as well as information; it involves persons and identities as well as messages. Moirand makes this point when she reminds us that popular science involves communicative as well as cognitive dimensions. Gülich raises interactive issues, even though her examples are monologues, because they are transcribed as the speech of a doctor trying to gauge, face-to-face, the responses of an audience. Ciapuscio traces formulations in the interactions between scientists and journalists. Calsamiglia and Ferrero show how interactions can be present in a polyphonic text. In any case in which scientific

with newspapers, not because these are necessarily the most influential sources of science news, but because they are more convenient materials for research).

This focus on written texts, even if it is traceable to purely practical considerations, limits studies of popularization. First, some of the most dramatic and memorable encounters with science are primarily visual, rather than verbal, whether it is Humphry Davy setting off great bolts of electricity in Royal Institution Lectures, David Attenborough grooming with gorillas in the BBC's documentary series Life on Earth, or pictures of the modified mouse with an ear on its back. Second, a focus on words ignores changes that are occurring in even the more traditional genres, such as textbooks, as new production technologies enable them to use more pictures and more complex layouts (Bastide 1991; Miller 1998; Veel 1998; Lemke 1998). Third, it limits the places we look for popularization, so we may tend to ignore classrooms (Kress et al. 2001; Ogburn et al. 1996), or science museums (Bud 1988; Durant 1992; Macdonald 1996), as well as television, films, and ads. Finally, the focus on the words in popular science texts tends to reinforce the assumption that popularization is just a matter of simplifying and perhaps distorting the original message provided by science. If we look more broadly at the ways people experience popular science, we see it as emerging from their lives, concerns, and everyday practices, whether taking notes in class, or taking the kids for a day out.

There are now good guides for text analysts beginning visual analysis (Kress and van Leeuwen 1996; Kress and van Leeuwen 2001; van Leeuwen and Jewitt 2001; Rose 2001). But even if discourse analysts do analyse visual aspects of texts, there remain practical problems for any attempt to incorporate these analyses in our arguments. Reproduction of visual images raises copyright issues. It also raises issues of technology; it is still expensive and difficult to include high-quality colour

Studies have focused, not only on the features taken to be characteristic of scientific discourse, but also on features that leap from scientific discourse to political, social, and cultural discourses (and back the other way). The links are often not matters of terminology, methods, or findings, but harder to pin down features such as metaphors (see Gülich for instance), narratives (e.g., Seguin 2001; Myers 1990b), and imagery (Bastide 1991; Myers 1990a; Miller 1998; Brown 1999). But discourse analysts have not yet fully responded to the message from the historians and cultural studies researchers, because we still often start with well-bounded disciplines. If we started instead with the scientific issues that concern the public, and took any one issue in detail, we would find ourselves wandering through a bewildering range of other discourses and genres. A study of DNA fingerprinting, on the face of it a scientific topic, found first in scientific journals, would lead to issues of chance and probability, guilt and innocence, race, nationality, and the conception of what it is to be an individual. When reporters frame news articles on DNA fingerprinting, they are thinking of these possible ways of relating the techno-scientific elements to the things people care about, and when readers pick up the articles they interpret them in terms of just these frames.

Words and other modes of communication

Research on popularization has focused overwhelmingly on the words of popular science texts, rather than visual elements, objects, embodied movement, or other codes. This focus is perhaps inevitable, since discourse analysts (and also historians, sociologists, and media studies scholars) have more tools handy for analysing words. Also, written texts are easier to collect, store, and analyse. (Gregory and Miller (1998, p. 105) point out that most media studies research on science deals

and enters back into the culture of the period, whether it is Boyle (Shapin and Schaffer 1985), Davy (Golinski 1992), Darwin (Desmond and Moore 1991; Young 1985), early nineteenth-century geology (Rudwick 1985), early twentieth-century statistics (Mackenzie 1981), or the whole history of the human sciences (Smith 1997). Science has been in every period a part of public culture, drawing on and contributing to ideas about nature, the place of humans in nature, the direction of history, the nature of government and economy.

Perhaps it might seem that these links had been severed with the emergence of professionalised disciplines and institutions, that these disciplines had become autonomous and followed their own internal logics in their development. But it is more likely that the links are harder to see, since our own cultural frameworks are just what we take for granted. Current cultural studies of science show the interaction of science with popular ideas on gender, race, kinship, progress, identity, sexuality, and social organisation (e.g., Franklin 1997; Haraway 1989; Nelkin and Lindee 1995; Traweek 1988) – one can see evidence in every issue of the journal Science as Culture. Metaphors cross over being scientific and popular discourses (Bastide 1992; Hedgecoe 1999; Väliverronen 1998; Väliverronen and Hellsten 2002; Hellsten 2003). To return to the example of the Measles Mumps Rubella vaccination, the vaccine was produced because of a widespread cultural model of disease and its prevention, it was promoted using epidemiological models of risk, and it is resisted because of other models of risk, responsibility for one's children, and trust in authority, and because of experiences with other episodes of risk and the reassurances and denials by authorities.

That scientific discourses are embedded in and intertwined with other courses is probably easy enough for discourse analysts (if not for some scientists) to accept.

explain one's project, and its relevance to wider society, in non-specialist terms, or to colleagues, is an essential part of running a large lab and getting further funding. And sometimes it is essential to be able to explain, again in nonspecialist terms, why a competing claim about global warming models, vaccination risks, or cold fusion is wrong. Only from the outside, and from a great distance, does scientific discourse seem to employ a single unified register.

The implication of this continuum for discourse analysts is that one needs to be very careful about how one aggregates texts to represent a discourse. Much of the research on popularisation has involved case studies of a single text (e.g., Myers 1990a; Selzer 1993; Fuller 1998). But as soon as one tries to go further, one raises complex questions of genre. Are the news articles at the beginning of Nature, drawing attention to more specialist articles in the issue, specialist or popularizing texts? How about grant proposals? Medical journal articles aimed at general practitioners? Advanced textbooks? Textual analysts, like practicing scientific writers, need to be prepared for hybridity. So any claim one makes, about the use of references, or the hedging, or the illustrations, needs to relate back to what this particular text is doing here, not to assumptions about what texts like this in general must do, and not to broad distinctions between real science and some imitation.

Science and other discourses

Just as the dominant view assumes a deficit model of members of the public, it assumes that the scientific information, when it arrives, is written on a blank slate of public culture. There is no sense in this view of the cultural schemas through which might make sense of science and make it relevant to their lives, except when these schemas are treated as outmoded commonsense, bias, ideology, and ignorance. Yet it is a clear message of history of science, in every period, that science emerges from

simplification. But discourse analysts must remember that scientific discourse involves a range of genres and practices, and that popularizations are an important part of this range. As Stephen Hilgartner says, 'popularization is a matter of degree' (Hilgartner 1990, p. 528.). The collection of texts one makes to show 'specialist' or 'popular' genres may itself be mixed in terms of its audiences, intentions, or register.

Developing a scientific claim and being a successful scientist require involvement in a range of genres: talking informally with colleagues, writing proposals that must be readable and persuasive outside the specialist field, delivering papers and responding to questions, all of what Hilgartner calls the 'upstream' side of a journal publication (1990, p. 528). More controversially, the success of a claim involves its being cited, featured in review articles (Bazerman and Paradis 1991), included in textbooks, and in some cases, reported in the media and in government policy documents – what Hilgartner calls the 'downstream' side of a journal publication. Just where does popularization start in this stream? In controversial cases, scientists can dismiss preprints, conference talks, review articles and government reports as simplifications, or they may claim these parallel forms of publication as embodiments of scientific authority (Lewenstein 1995a).

The continuum is not just a matter of a range of genres; within each genre there may be a range of registers or repertoires, different ways of speaking for different rhetorical purposes. Any detailed study of the practices of scientists shows that they do not confine themselves to the kind of language used in published scientific articles; they move between several repertoires (Latour and Woolgar 1979; Myers 1990c; Gilbert and Mulkay 1984). The informal uses of language cannot be ruled out as unscientific; it is in casual talk that the science gets done as a practical matter (Lynch 1985; Knorr-Cetina 1981; Ochs and Jacoby 2000). Being able to

her child had these symptoms just after the jab is enough to reawaken fears and reduce the take-up of the vaccinations.

It is just this sort of resistance to scientific expertise that maddens scientists, because they see it as a blinkered refusal to participate in the benefits brought by scientific progress and a scientific world view (Wolpert 1992; Gross and Levitt 1994; or for a more nuanced and witty discussion, Dunbar 1995). But one need not re-open the debates about the authority of science (called in the US 'The Science Wars') to see that debates in the public sphere have to draw on arguments that work in the public sphere. Specialist expertise gives some strong arguments in this sphere, but they are not the only possible arguments.

If claims to expertise are not to be found only in scientific journals and scientific institutions, then researchers who want to understand public understanding of science have to look beyond collections of research articles, and consider all the ways people attribute or claim expertise in discourse. This may involve studying popular science texts as part of scientific discourse in their own right, and examining their use of the literature or presentation of the authors or qualification of claims (Selzer 1993; Fuller 1998; Nelkin 1987; Lewenstein 1995a; Myers 1990b). But it may just as well involve studying other forums, such as the once-popular pedagogical genre of 'conversations' (Bahar 2001; Myers 1989b), or meetings of workers held in pubs (Secord 1994b; Secord 1994a), or internet newsgroup exchanges on rapidly breaking news of a risk in the food chain (Richardson 2001).

The continuum of popularization

In the dominant view of popularization, a research article (preferably just one) is the ultimate source of undiluted and undistorted science. For some approaches, for instance bibliometric studies of scientific disciplines, that may be a useful

medical syndrome may have a considerable knowledge of that syndrome. Opponents of nuclear power (as well as companies promoting it) have a considerable knowledge of the science of nuclear hazards and the technology or nuclear waste storage. Farmers know about the grazing habits of sheep, and if they have been subject to controls after nuclear contamination, they may know about that too (Wynne 1996a; Wynne 1996b). Bantam breeders may know a great deal of practical genetics. Patent attorneys may surprise their clients with their knowledge of the science behind an invention. (See the journals Public Understanding of Science and Science as Culture for many studies along these lines). These areas of specialist knowledge are unevenly distributed; more people are interested in health and risk issues than in, say, algebraic theory or materials science (or linguistics). But there is no reason to expect the specialisms of contemporary science to map onto the categories of contemporary public interest.

Members of the public who challenge scientific claims will never have the same sort of authority as scientific experts, because they cannot marshal the same networks of support for their claims (Latour 1987). Scientists would point out that the public should not have the same kind of authority, because their claims have not been subjected to the kind of challenges that claims undergo in scientific discourse (Bazerman 1988). But members of the public have their own persuasive resources, because they can connect the abstractions of scientific knowledge to lived experience, and public debates provide their own sorts of challenges to arguments. Consider for instance the controversy in Britain about the possible link between the Measles Mumps Rubella 'triple jab' and some forms of autism. The weight of published medical research, institutional policy, and doctors' advice is firmly on the side of the relative safety of the vaccination. But a radio interview with a mother who says that

the explosive growth of scientific research, and have had many beneficial effects, but they were not inevitable or intrinsic to the subject matter of science.

Second, experts become less expert as soon as they step outside their very limited specialism. A professional scientist might read or teach in areas far removed from their day-to-day research, and in those areas they have to rely on mediators: employing recently-trained post docs, plowing through review articles, even reading textbooks or Scientific American. In media interviews, a developmental biologist might be treated as expert in all areas of biology, or even all areas of science and technology – but the biologist will not expect to be treated this way by their colleagues. When I go to the doctor, I treat her as an expert in medicine, but her relation to current medical research will generally be as a continuing student, not as a participant, and the medical journals have to perform a kind of popularizing function for her. Administrators, medical students, patent lawyers, post-docs, technicians, science journalists, and research scientists in commercial firms all take on, sometimes uncomfortably, an identity between expert and lay. Yet such boundary figures are essential to the maintenance of science and technology.

Nor is the public entirely cut off from expertise. It is true that surveys show again and again that members of the public cannot be counted on to know any specific piece of scientific information, however basic (Durant et al. 1989). Thus studies of the Public Understanding of Science have tended towards what have been called deficit models (Wynne 1995), attempts to account for the boundless ignorance of people who don't know the difference between a virus and bacteria, or don't know how DNA works. But if one starts at the other end, and asks what members of the public do know, about the areas of science and technology that concern them, one might be surprised (Irwin and Wynne 1996). The parents of a child with a rare

challenges for textual studies. We need to question who the actors are, how the various discourses interact, what modes are involves, and what it is that is communicated – and we need to consider what these questions imply for text analysts.

Expert and lay audiences

In the dominant view of popularization it is assumed that expert and lay audiences are divided by a vast gulf. And this would certainly seem to be true, when as academics we browse in any section of the library apart from our own, or when we see how topics from our own specialist subjects are reported (if they are reported at all) in the media. The gulf is clear enough when the Nobel Prize-winning physicist Steven Weinberg writes a popular book on contemporary cosmology for non-physicists: he is clearly an expert, and I am not. (I would like to think that on matters of discourse analysis I would be considered an expert and Professor Weinberg a lay reader, but I am not sure this distinction would be so readily accepted by most members of the public or by policy-makers). Despite being so apparently self-evident, the distinction between expert and lay audiences breaks down almost as soon as we try to apply it more widely.

First, the sharp division between natural science and other areas of knowledge turns out to be of relatively recent origin. In the eighteenth and nineteenth centuries science was open to wider discussion among gentlemen (the restrictions of gender and class were often taken for granted) (Atkinson 1999; Lightman 1997; Bensaude-Vincent 2001; Cannon 1978; Cooter and Pumfrey 1994; Gates and Shteir 1997; Golinski 1992; Myers 1992; Myers 1989b). One by one disciplines were institutionalized and amateurs excluded, for instance geology in the early nineteenth century, psychology not until the end of the century, linguistics not until the twentieth century. The professionalization and specialization have played an important role in

focusing on written texts, looks at spoken interactions that cannot be seen as one-way transfers of information. Giomar Ciapusco also stresses the importance of interactions between scientists and intermediaries such as science journalists. Sophie Moirand argues that popularisation is not a linear process, from scientist to public, but a circuit. It involves communicative as well as cognitive dimensions, and it is not written on a blank slate of public ignorance, but enters into an 'interdiscursive memory bank'. Helena Calsamiglia and Carmen Lopez Ferrero treat the quoting of both scientists and non-scientists within a larger framework of reported speech, so it is no longer a special case of the accurate or biased transfer of scientific knowledge, but a more general question of the construction and evaluation of actors in texts.

Each of these studies treats popularisation, not just as a category of texts, but as a process that opens up questions about the actors, institutions, and forms of authority involved. One way to think of these changes is to see science, not as a discourse, a single set of social practices around one thing, but as an order of discourse, a terrain of competing discourses and practices (Fairclough 1992). Popularisation is a routinized social activity that has led to the creation of a number of fairly stable genres –one Scientific American article will have a very similar structure and style to another, or one newspaper feature article on, say, DNA fingerprinting, will have the same sorts of metaphors and rhetoric as others. There is a temptation to stop there, with that description, but if we are going to draw wider implications from these analyses, we need to place them in the wider terrain of competing discourses.

In this review, I will not try to review all the fields that have contributed to studies of popular science texts (for overviews, see Shinn and Whitley 1985; Lewenstein 1995b; Gregory and Miller 1998; Bensaude-Vincent 2001), but focus on some of the challenges to the boundaries of the field, and the implications of these

- and that in the course of translation from one discourse to the other, this information not only changes textual form, but is simplified, distorted, hyped up, and dumbed down. (The French term vulgarisation carries even more of this pejorative sense).

It is not surprising that this dominant view of popularisation is so prevalent, because it is the view of the process as seen from within scientific institutions, and it is the view promoted by those institutions (e.g., Royal Society of London 1985).

Such a view of science as a discourse and popularisation as a genre, natural as it may seem, carries with it some assumptions about how texts should be studied. Following the dominant view, a set of texts could be identified to stand for popular science (articles in Scientific American, or best sellers on cosmology, reports in newspapers, or transcripts of television documentaries), and these texts could be compared to another set of research articles in scientific journals (such as Nature or Cell) that could be taken as the originals, perhaps even matched up as the sources of those popular texts. There will certainly be some differences in textual form, in the sentence subjects, grammatical voice, verb choices, modality and hedging, and of course the rhetorical structure. These differences can then be related back to the special qualities of scientific institutions, and applied to issues of teaching, translation, or public awareness. My own studies a decade ago question the linear nature of the diffusion of knowledge, but still take for granted some of these assumptions about popularisation, especially in their focus on selected written texts (Myers 1989a; Myers 1990c; Myers 1990b; Myers 1991).

The papers collected in this issue show how some of the assumptions of this dominant view are now being questioned in textual studies. For instance Elisabeth Gülich questions the boundary between expert and lay participants, and instead of

Scientific American, or a science journalist reports it in the Times, or when a television documentary shows the scientist walking across a leafy campus, the same material becomes popularization.

The interest in popular science texts comes from applied linguists seeking to improve the teaching of languages for academic purposes (Myers 1989a), rhetoricians seeking to relate scientific discourse to other discourses (Fahnestock 1986), science studies scholars interested in the relation of science and society (Whitley 1985), science communication scholars interested in the practices of journalists and this special case of media effects (Lewenstein 1995b), historians placing science within public culture (Pumphrey and Cooter 1994), and not least, scientists themselves (Haldane 1985; Wolpert 1992; Dunbar 1995).

Researchers such as those in this issue are likely to question some of the boundaries that have been assumed for popular science. Earlier textual studies tend to fit within what has been called a 'dominant view' (Hilgartner 1990) or a 'canonical view' (Grundmann and Cavaillé 2000) of popularization. This view assumes that there are two separate discourses, one within scientific institutions and one outside them, that information is translated from one of these discourses to the other. There are several assumptions that go with this view:

- that scientists and scientific institutions are the authorities on what constitutes science,
- that the public sphere is, on scientific topics, a blank slate of ignorance on which scientists write knowledge,
- that this knowledge travels only one way, from science to society,
- that the content of science is information contained in a series of written statements,

Discourse Studies of Scientific Popularization: Questioning the Boundaries

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Abstract

This paper critiques a 'dominant view' of the popularization of science that takes it as a one-way process of simplification, one in which scientific articles are the originals of knowledge that is then debased by translation for a public that is ignorant of such matters, a blank slate. It surveys recent work in several disciplines that questions boundaries of scientific discourse and genres of popularization: who the actors are, how the discourses interact, what modes are involved, and what is communicated. It draws implications from these studies for discourse analysis.

Introduction

The popularization of science is an unusual field for discourse analysis, because the scope of the field is defined in terms of what it is not. There is no field that names all discussions of crime and punishment except those published in law journals, or all discussions of God except those given the imprimatur of an established church, or all discussions of politics except those in government documents. Popularization includes only texts about science that are not addressed to other specialist scientists, with the assumption that the texts that are addressed to other specialists are something else, something much better: scientific discourse. An article in Cell does not belong in this field, but when the same author writes it up in