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ABSTRACT

This paper discusses the relationship between the work that takes place in science laboratories and the science curriculum that is presented in the schools. The introduction asserts that although science education identifies itself with the scholarly disciplines of science, science educators should devise curricula that fairly represent these disciplines to learners. The second section proposes that science textbooks misrepresent science through oversimplification and that school science laboratories have fictionalized the science laboratory. The third section discusses the image of scientific work as depicted by textbooks and the realities of what is done in scientific laboratories. The fourth section discusses the politics of scientific writing and the potential power science exerts. The final section suggests that school laboratories do not resemble the work sites of professional scientists and proposes that school laboratories are more suited for object-oriented play and exploration. (Contains 18 references.) (MDH)

LABORATORIES IN SCHOOL: MATERIAL PLACES, MYTHIC SPACES

Noel Gough

Paper presented at the Annual Meeting of the American Educational Research Association
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Laboratories in schools: material places, mythic spaces

Paper presented in a symposium: 'Give me a laboratory and I will move society': critical perspectives on 'scientific' production and the construction of school knowledge

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Preamble

The title of this symposium was suggested by Bruno Latour's (1983) paper: 'Give me a laboratory and I will raise the world'. In elaborating upon his parody of Archimedes' well-known aphorism[1], Latour argued that laboratories manufacture meanings which function as cultural 'levers' to 'move' society in various ways. All of the participants in this symposium are concerned with the 'leverage' that science exerts in schools. My particular concern is with the relationship between cultural production in sites of scientific labor ('laboratories') and the construction of school science curricula.

As Schwab (1973) and others have argued, developing a defensible curriculum requires much more than simply 'translating scholarly material' into a subject matter to be taught and learned. Nevertheless, given that science education identifies itself with the scholarly disciplines of science (and given that science is a significant expression of Western industrial society's values and goals), science educators have a moral obligation to 'play fair' when they devise curricula which represent these disciplines to learners. Scientific work produces meanings which are translated, interpreted and selectively legitimated by many constituencies including, for example, academics, journalists, teachers and learners. These meanings contribute in various ways to a mythology of science that is embodied in the discourses, practices and material conditions of school science education. I will argue here that several aspects of this mythology are deeply problematic and dysfunctional and, therefore, require the critical and creative attention of science educators and other curriculum workers.

School science as a science fiction

Conventional learning in school science can be characterised by its dependence on a special kind of print medium — 'the textbook'[2] — and a special kind of classroom: 'the laboratory'. Among the purposes and functions attributed to both textbooks and laboratories are those concerned with *representing* the cultural manifestations of 'science' to learners. However many (perhaps most) textbooks *misrepresent* science by incorporating idealised, oversimplified and outdated accounts of scientific work and its consequences[3]. Similarly, most school laboratories are crude stereotypes of the diverse sites in which scientists pursue their labors. The work that is done in them — indeed, the work that *can* be done in them — bears little or no resemblance to contemporary professional practice in the physical and biological sciences. This has been exacerbated by the rise and spread of highly bureaucratised and technologised 'big science'[4] which, especially in the physical sciences, requires very different facilities from those on which school laboratories are modelled. Little of what now counts as 'progress' among communities of working scientists is accomplished by the sort of individualistic, small-scale, low-tech 'bench work' to which school laboratories are suited. While the design of existing school laboratories may be a legacy of the days of 'small science', I doubt that nostalgia for this

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1. 'Give me a lever and I will raise the earth' is the simplest version although it is sometimes rendered as 'Give me a lever long enough, a fulcrum and a place to stand and I will raise the earth'.
2. It should be noted that textbooks differ in significant ways from other media that we label 'texts' and 'books', though it is beyond the scope of this paper to pursue the implications of these differences.
3. See below and Gough (in press) for substantiation of this assertion.
4. also known as 'Berkeleitis' in honor of its alleged origins in the work of high-energy physicists at Berkeley after the Second World War.

era is among most science educators' justifications for their continued existence[5].

School science textbooks and laboratories are, quite literally, *science fictions* in the original sense of *fictio* — that is, something fashioned by a human agent. But laboratories in schools have become places where scientific work is fictionalised in ways that seem likely to impede learners from understanding the meaning and significance of scientific production in our society and culture. In the discussion which follows, I will focus on two broad ways in which laboratories in schools fail to represent science to learners in an educationally defensible fashion. First, the routine activities that are conducted in school laboratories neither emulate nor simulate 'real' scientific work but, rather, reiterate stereotypical and mythologised conceptions of science and its methods. Second, these activities usually are conducted without reference to (or representation of) the ideological commitments that animate scientific work or the political strategies through which it exerts authority in our society. Thus, laboratories in schools may actually serve to 'double insulate' learners in science education programs from understanding what scientists actually do — *and do not do*. As Linda Gordon (1986) claims for history, no 'objective' truths may be possible, but there *are* objective lies. There can be better and worse science fictions; there can be better and worse representations of science in schools.

Representing scientific labor (i): the misconstruction of method

In Donna Haraway's (1989: 368) words: 'Laboratories are the material and mythic space of modern science'[6]. During the last two decades, a number of studies of scientists at work (eg Latour 1983, Latour and Woolgar 1979, Mitroff 1974, Charlesworth et al 1989) have explored these material and mythic spaces in some detail, illuminating differences between what is actually done in laboratories and what Mitroff (1974: 8) calls 'the storybook image of science' — an image constructed from what scientists say they do and what society at large believes they do. This 'storybook' image or myth permeates the majority of conventional science education textbooks and several aspects of it are apparent in the most recent draft of *A National Statement on Science for Australian Schools* (Australian Education Council 1991). The *Statement* begins by describing 'The Characteristics of Science' (AEC 1991: 4) as follows:

> Science is among our greatest achievements. It has revolutionised the way we think about the world and the way in which we live. Using the principles and processes of science we can construct useful and reliable explanations and knowledge of the natural and physical world.
>
> The principles of science give validity and rigour to scientific explanations...

The *Statement* then lists a number of familiar examples of these principles ('respect for evidence', 'testable and falsifiable hypotheses' etc) and processes ('predicting, observing, testing hypotheses and models, collecting, classifying...' etc). Much of the remainder of the *Statement* is devoted to elaborating 'the scope of science education' in terms of two 'process strands' ('investigating in science' and 'understanding and applying scientific knowledge') and four 'conceptual strands' ('life and living', 'energy and change', 'natural and processed materials' and 'earth and space'). The *Statement* as a whole thus characterises science in terms of explanatory concepts and generalisations whose warrant and status are justified by a particular way of thinking. While the *Statement* does not ignore the social and cultural dimensions of scientific production, it asserts nevertheless that the truth claims of scientists are privileged by the special qualities of the method that is used to produce them: '*Although* science is socially constructed, the processes and principles of science *still* enable scientific knowledge to be developed which is generally reliable, useful and well accepted' (AEC 1991: 4; my

5 Since much of what is presently taught in school science deserves to be treated as history ('Once upon a time there was a man called Isaac Newton who...') rather than truth ('Newton's first law of motion is...'), maintaining school laboratories as relics of experimentalism is defensible; indeed, simulations of classic instances of 'bench work', from William Harvey to Marie Curie, could be extremely generative points of departure for considering critically the cultural meanings they have produced.

6 It is beyond the scope of this paper to pursue the question of the extent to which laboratories are also the material and mythic space of *postmodern* science. Suffice it to say that postmodernisms suggest increasing attention to the mythic space and to the overlapping (fused/confused) boundaries of the material and the mythic. While the following analysis is sympathetic to postmodernisms, I am primarily concerned with the problems of representing contemporary science (a key cultural site for contesting modernist/postmodernist paradigms) to learners in some honest and virtuous way.

emphases[7]).

Studies of laboratory scientists at work provide numerous grounds not only for questioning this apparent faith in the products of experimentalism but also for disputing the textbook image of scientific work. For example, Charlesworth et al (1989: 271) conclude that: 'What strikes one forcefully as one looks at the way scientists carry on in reality, is the enormous disparity between that reality and the idealized or mythical accounts of it that are given by both observers of science and scientists themselves'.

One of the more persistent and pervasive myths is that scientific work is characterised by a special kind of method. But as Latour (1983: 141) writes:

> Now that field studies of laboratory practices are starting to pour in, we are beginning to have a better picture of what scientists do inside the walls of these strange places called 'laboratories'... The result, to summarise it in one sentence, was that nothing extraordinary and nothing 'scientific' was happening inside the sacred walls of these temples.

Charlesworth et al (1989: 271) reached similar conclusions:

> ...the neat classical picture of deductions being made from theories and then tested by observation and experiment (the so-called hypothetico-deductive method) scarcely ever corresponds to the reality of the scientific process. Much of scientific investigation relies on a pragmatic 'let's try it and see what happens' approach, and the getting of data is all important...
>
> Instead of concentrating on 'the method' of science as philosophers of science from Bacon to Popper have done, then, we should fix our attention on... 'data generation systems', involving techniques, instrumentation, experimental materials (mice, sheep) co-ordinated networks and so on.

Data generation systems typically are designed to transform experimental materials into specified forms of inscription. For example, during his studies at the Salk Institute, Latour (1986: 15) claims to have been struck by the way in which many features of laboratory practice could be ordered by looking 'not at the scientists' brains (I was forbidden access!), at the cognitive structures (nothing special), at the paradigms (the same for thirty years), but at the transformation of rats and chemicals into paper. ... the way in which anything and everything was transformed into inscriptions...was what the laboratory was made for...'. Latour (1986: 3-4) also emphasises the extent to which laboratory scientists depend on the inscribed products of data generation systems: 'their end result, no matter the field, was always a small window through which one could read a very few signs from a rather poor repertoire (diagrams, blots, bands, columns)... When these resources were lacking, the selfsame scientists stuttered, hesitated, and talked nonsense...'. In other words, while the discursive authority of science in society and education is supported by the mystique of 'scientific method', the truth claims in which working scientists have confidence appear to be restricted to whatever is expressed through their inscription devices — the ways of writing and diagramming that are specific to the data generation systems they have constructed.

Many science education policies and curricula are thus founded on a spurious representation of the interrelationships between data generation systems, 'scientific knowledge' and 'scientific method'. For example, in the *National Statement on Science for Australian Schools* cited above, data generation is presented as though it invariably takes place as part of a rational sequence of activities that can be described in terms of the 'scientific method' for producing 'scientific knowledge'. Such a rationalisation ignores the pragmatics and social determinants of data production (not to mention the imagination, skill and ingenuity with which laboratory scientists develop data generation systems and inscription devices for particular purposes). Furthermore, as Charlesworth et al (1989: 271) observe, 'irrational and uncontrollable factors — lucky breaks, playing one's hunches, being in the right place at the right time — also play a disconcertingly large part in scientific discovery'.

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7 It is worth considering what may be implied by the use of the terms 'although' and 'still' in this sentence. Are the authors suggesting that the social construction of knowledge diminishes its reliability, usefulness and acceptability? It is as if the authors are apologising for science being socially constructed, but then reassuring the reader that, nevertheless ('still'), this troublesome complication can be overcome by applying 'the processes and principles of science' — as if social constructedness is a curable disease. This rhetorical ploy reasserts the privileged status of scientific knowledge by implying that scientific method transcends social construction.

If the rationalised version of scientific method 'scarcely ever corresponds to the reality of the scientific process' then the privileged status of 'scientific knowledge' must be questioned. The argument that 'the processes and principles of science... enable scientific knowledge to be developed which is generally reliable, useful and well accepted' (AEC 1991: 4) is difficult to sustain in the light of evidence that these 'processes and principles' do not characterise the work of practising scientists. Indeed, the studies of scientists at work cited here clearly demonstrate the *underdetermination* of scientific truth claims by the evidence that is claimed to support them. Despite the myth of the definitive experiment which reliably separates truth from error, very few 'well accepted' hypotheses are discarded simply on the basis of experimental refutation. Textbook accounts of scientific method rarely acknowledge that any one experiment usually supports several alternative hypotheses[8], that experiments may be easier to design than to carry out, and that many experimental results are much less clear cut than is suggested by the reductionist forms of inscription and interpretation in which they are presented. A 'well accepted' theory may be supported by one selection of data and undermined by others. To say that a given scientific theory is 'reliable, useful and well accepted' does not mean that it has emerged from rigorous application of the textbook version of scientific method but, rather, that it constitutes a social agreement constructed by the participants in a particular 'conversation'.

Representing scientific labor (ii): science is politics by other means

To understand how a scientific theory can be both 'well accepted' and underdetermined by data requires that we look beyond the material space of laboratory work to the 'mythic space' constituted by the cultural discourses in which scientists participate. The work of critical feminist scholars has been particularly illuminating in this respect. For example, from her synthesis of several detailed examinations of scientific theories of gender difference, Ruth Bleier (1986: 58) concludes that

> the notion that significant cognitive sex differences exist and that explanations for them may be found by looking for biological sex differences in the development, structure, and functioning of the brain... is legitimized by an elaborate network of interdependent hypotheses.... Standing alone, few of the hypotheses have any independent scientific support, but together, supported by each other, they create the illusion of a structure of weight, consistency, conviction, and reason. In support of [their commitment to scientific theories of gender difference], scientists make increasing numbers of unsubstantiated conjectures that are then taken up by other scientists as confirming evidence for their own unsubstantiated conjectures.

Bleier's example draws attention to a dimension of scientific production that is conspicuously absent from textbook versions of scientific method and attempts to simulate scientific work in school laboratories: science is not only a matter of generating data and inscribing them in the material spaces of laboratories but also involves the generation, transformation and interpretation of meanings in the mythic space which laboratories symbolise. To quote another example of Bruno Latour's (1984: 257) appropriations of famous sayings[9], 'La science, c'est la politique continuee par d'*autres* moyens' ('science is politics continued by other means'). Latour emphasises that his view does not 'reduce' science to politics — to arbitrary power rather than rational knowledge. Rather, Latour directs attention to the importance of discerning the 'other means' by which scientists exercise political power. These include particular narrative strategies and the authority to deploy them with a given audience. It is in scientists' interests to maintain what Haraway (1986: 83) calls a 'mystifying dichotomy' between power and knowledge — to be able to claim that they are doing research rather than practising politics when they are wittingly or unwittingly doing both. One way of sustaining this dichotomy is by separating 'research' from the language in which it is conceived and reported. As Judith Brett (1991: 519) writes:

> Scientists do their research, then write it up. The writing is seen as ancillary, after the fact, and in no way constitutive of the research itself. The adoption of this way of talking about research masks the centrality of language and writing... The fiction is of reality apprehended before language and of the act of writing as a simple one of reporting on or describing that apprehension. The true work is thus seen as collecting the

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8 A notable exception is T.C. Chamberlin's (1890) classic paper acknowledging the 'method of multiple working hypotheses'.

9 'war is politics by other means', an early 19th century aphorism attributed to von Clausewitz.

> facts,... the findings, and the writing is simply the report, written in the plain impersonal style characteristic of reports, as if the author were absent. The role of language in shaping and probing reality is denied...

In other words, scientific writing masks the extent to which scientists' language produces the data they report. The narrative strategies of scientific writing (such as the use of the passive voice) create an illusion of neutrality, objectivity and anonymity which contributes to the authority of the text. Scientists tend to write as though language is merely another inscription device — a vehicle for transmitting data about the objects and outcomes of their research — rather than a medium which generates a multiplicity of meanings. The meaning of a scientific report is not fixed in the printed words or in their representation of an author's intentions but, rather, in the reading of the report by others, such as colleagues, students, science journalists and members of the public. The strategic effect of deploying a façade of neutrality is captured well by Bleier in relation to the reporting of a number studies of human and rat brains which purport to provide evidence of sex differences in the hemispheric lateralization of visuospatial function:

> However unreflective the process may be, scientists... are able to stop just short of making the kinds of assertions that their own and others' data cannot defensibly support, yet they can remain secure in the knowledge that their readers will supply the relevant cultural meaning to their text; for example, that women *are* innately inferior in the visuospatial and (therefore) the mathematical skills, and that no amount of education or social change can abolish this biological gap. It is disingenuous for scientists to pretend ignorance of their readers' beliefs and expectations and unethical to disclaim responsibility for the effects of their work and for presumed misinterpretations of their 'pure' texts. Scientists are responsible, since they themselves build ambiguities and misinterpretations into the writing itself.

When Latour (1983: 141-2) reported his investigations of laboratory life he was impelled to ask a 'naive but nagging question: if nothing scientific is happening in laboratories, why are there laboratories to begin with and why... is the society surrounding them paying for these places where nothing special is produced?' But as Damien Broderick (1987: 33) suggests, we might just as well ask:

> If nothing metaphysical was happening in medieval monasteries, as plenty of atheists would surmise, why did society pay for *them*? If nothing of security is being fostered by the overwhelming multiplication of nuclear weapons and 'conventional' arms, why are we all paying so much for them? The answer, as always, lies at the intersection of power and knowledge. Religion and the profession of arms and the exercise of theoretical and laboratory skills are all arenas for the deployment of authority, the insertion of levers, the exertion of force.

As we well know, the force of science can be exerted for both good and ill. Science educators must consider how best to represent science in schools so that both its virtues and its vices are understood and so that learners are invited to participate in the transformation of science's oppressive power (for example, by resisting and challenging the strategic rhetoric of scientific writing which allows a passive voice to command such coercive authority). This should lead us to consider the purposes and functions that laboratories might serve in such a critical science education.

Whither school laboratories?

While certain kinds of laboratories may be necessary for the forms of labor and production in which many scientists engage, it does not follow that the kinds of laboratories that can be found in schools and universities are either necessary or desirable for learning in science education or, indeed, in science teacher education[10].

As material places, school laboratories neither resemble the sites in which most scientists work nor are they used for the kind of experimentation and data generation that characterises

10 As a teacher educator, my interest in this issue was initiated by the *Report of the Discipline Review of Teacher Education in Mathematics and Science* (Department of Employment, Education and Training, Australia 1989) in which several teacher education institutions are rebuked for their lack of a 'teaching methods laboratory'. Many Australian science teacher educators have used this criticism as a lever to prise funds from institutional budgets to establish such laboratories.

much professional science. Rather, they are places where students follow recipes, perform routine procedures, rehearse technical skills (eg manipulating apparatus, monitoring instruments, measuring and recording etc.), demonstrate the reliability of selected ('well accepted') scientific 'laws' or phenomena — and falsify their data when the procedures and demonstrations produce inconclusive or 'unexpected' results. By tolerating and tacitly approving the falsifying of data, science educators not only contradict their own mythology — faith in the 'scientific method' — but also trivialise the activities that are most central to the working lives of professional scientists. In my own experience, the best examples of school students undertaking 'real' science have been those which involve them in either working *outside* school laboratories (eg investigating local environmental problems which necessitate collection of data in fieldsites; see Greenall Gough and Robottom in press) or substantially modifying them (eg teachers and students in one Melbourne suburban high school devised and built a sophisticated satellite communications monitoring facility around which much of their physics course was based).

The material conditions of school laboratories do not lend themselves to critical explorations of the mythic spaces they symbolise. School laboratories are designed and equipped to support 'hands on', unreflective 'busy work' rather than the kinds of activities through which learners might come to understand science as 'politics continued by other means'. Such activities include close analysis of the 'cultural texts' of scientific production — scientific journalism in the print and electronic media, science fiction in its myriad forms, representations of science in the fine arts — and studies in the history and philosophy of science.

While school laboratories in their present form have limited usefulness in a critical science education, there is at least one kind of educationally worthwhile activity to which they *are* materially suited, namely, object-oriented play and exploration. School laboratories are places where students can experiment with objects and phenomena in the pre-Baconian sense of 'experimental' — based on experience. However, it might be better if such experiential learning were not burdened with the label 'science' and the kinds of rationality that the myths of science impose. We can devise opportunities for children to exercise their curiosity and their senses without overlaying them with a 'scientific' justification. Creative play is a legitimate part of scientific work, but play does not need to be rationalised as 'science' to be legitimated. For example, children have been happily making and flying kites for centuries, and I doubt if their experience is enriched by teachers rationalising kite making in terms of forces, vectors and trigonometric functions. The idea that their learning will be more 'meaningful' within such a conceptual framework is a conceit of modern science and a poor excuse for colonising and appropriating children's own myths and imaginings. Rather than conceiving school laboratories as a simulacrum of 'the material and mythic space of modern science', we could perhaps do worse than to reconceive them as extensions of the material and mythic space of the playground.

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