Science and/or fiction? Narrative complexity and science education

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Introduction

This paper extends recent critical studies (Gough 1992ab, in press) of the dominant discursive practices of science education and explores further some alternatives among the narrative strategies which may be used to represent science – and especially postmodern science – to learners. The overall purpose of these inquiries and explorations is consistent with a project that David Ray Griffin (1988: 1) has named ‘the reenchantment of science’:

At the root of modernity and its discontents lies what Max Weber called ‘the disenchantment of the world.’ This disenchanted worldview has been both a result and a presupposition of modern science and has almost unanimously been assumed to be a result and a presupposition of science as such. What is distinctive about ‘modern’ philosophy, theology, and art is that they revolve around numerous strategies for maintaining moral, religious, and aesthetic sensitivities while accepting the disenchanted worldview of modernity as adequate for science. These strategies have involved either rejecting modern science, ignoring it, supplementing it with talk of human values, or reducing its status to that of mere appearance. The postmodern approach to disenchantment involves a reenchantment of science itself.

This paper explores one proposal for reenchanting science education, namely, replacing (or at the very least supplementing) the simple and simplifying discursive practices of conventional science education with the complex and complicating textual strategies that characterise much literary fiction, especially postmodern science fiction.

Science or fiction? Mayakovsky’s Cyberantics

Once upon a time, a brilliant, eccentric and very controversial cyberneticist by the name of Stanislaw Mayakovsky built a cybernetic ant (Prosser 1992). This miracle of micro-miniaturisation, known as A7 (but named ‘Ari’ by Mayakovsky), closely replicated the structural and functional qualities of the ant species (Formica subsericea) she was designed to resemble. She was equipped with a holographic memory and tiny (but very sophisticated) biotechnological systems which enabled her to communicate with other ants – she could decipher the semiochemicals of

other ants and synthesise pheromones appropriate for her own use in virtually any circumstance. A7 was a true replicant – in many senses of the word. To test A7's capabilities in the field, Mayakovsky sent her into a nest of 'real' ants. Not only was she accepted by these ants, but she also played a significant role in ensuring the colony's continuity in the face of the accidental loss of its queen and an invasion by a related species of 'slave-making' ants (Formica subintegra).
One of Mayakovsky's eccentricities was that he did not present his findings in the usual way, that is, by publishing them in a scientific journal. Rather, he told the story of A7's construction and susequent adventures by writing an illustrated children's book, Cyberantics, which became a best seller and was even awarded a major prize in the field of children's literature. Many of Mayakovsky's colleagues were incredulous at what he claimed to have achieved – and scandalised by his means of communicating it – but he remained oblivious to criticism and, partly as a result, his work fell into disrepute in the artificial intelligence research establishment.

Some years later, Mayakovsky disappeared under mysterious circumstances, and his work might have faded into obscurity were it not for the recent – and equally mysterious – reappearance of A7. This event prompted Prosser (1992) to publish the annotated edition of Cyberantics. A particularly interesting note accompanies a drawing in the first edition that outraged both entomologists and cyberneticists. This drawing, which shows A7 vanquishing a spider many times her size, revealed that Mayakovsky had equipped her with a miniaturised cold plasma laser weapon. As Prosser (1992: 30) writes:

He gave an ant a gun and presented his findings as a children's book. He once replied to criticism…by saying: 'It is only the limited imagination that takes refuge in the banal structures of formal science. A childlike sense of wonder and curiosity transcends these limitations and is more faithful to the aims of science than academic dogma and conceit. This is why I wrote for children.'

My purpose in this paper is a little like Mayakovsky's, but my concern is with some of the 'banal structures' and simplistic textual practices of formal science education. Also, like Mayakovsky, I wish to present an alternative. I will argue here that much fiction (including children's fiction but more especially science fiction) is 'more faithful to the aims' of science education than the 'dogma and conceit' of many contemporary science education texts.

Curriculum as storytelling
Like Madeleine Grumet (1981: 115), I find it useful to think of curriculum as 'the collective story we tell our children about our past, our present and our future'. In the course of pursuing a number of interrelated narrative inquiries in teacher education, my attention has been drawn to considerations of the quality of the stories we tell in several curriculum areas, including science education. In particular, I have been concerned to

examine the adequacy of the narrative strategies used by science educators in their work. That is, science teachers, policy makers, curriculum developers, textbook writers and the like tell stories of science to learners; scientists, science journalists and the authors of science fiction in various media also tell stories of science to their respective audiences. Each storytelling practice incorporates a particular selection of narrative strategies and conventions, the implicit or explicit knowledge of which influences the storymaker's craft, the audience's expectations and the meanings that are mutually constructed.

However, we should not take it for granted that the persistence of more-or-less distinct differences between the narrative forms found in, say, scientific reports, school textbooks, mass media journalism and fiction means that these differences are either necessary or desirable. For example, as Mayakovsky demonstrated, the narrative form in which the results of a technological innovation are reported is not determined by imperatives intrinsic to the activity itself, other than the social agreements that may exist from time to time among communities of inventors and technologists. It is possible for such work to be reported using the narrative strategies of children's picture books – but it would require more of these practitioners either to think like Mayakovsky or to find other persuasive reasons for accepting the legitimacy of such textual practices.

Similarly, the narrative conventions of science education textbooks are not necessarily the best or only means of describing and explaining science to learners. Biographies of scientists provide one obvious alternative (and, indeed, are used as ancillary texts by at least some science teachers) and other possibilities include poetry, drama, short stories and novels. For example, Janette Turner Hospital's (1988) novel, Charades, is infused with metaphors and other narrative elements adapted from or inspired by quantum mechanics. This story of twenty-four-year-old Charade Ryan's search for her own origins unfolds largely through 'pillow talk' – conversations between Charade and her lover, Professor Koenig, who teaches physics at the Massachusetts Institute of Technology. One such conversation (Hospital 1988: 191) includes the following exchange:

'Question,' Charade says. 'If a woman stands in the middle of Massachusetts Avenue facing MIT, but her memory is so vividly snagged on one particular day of her childhood in the village of Le Raincy that she is unaware… that she is oblivious to the cars around her and so she is hit, run over, killed… Is she more truly in Boston or France when she dies?'
'Well put,' Koenig says. 'The indeterminacy problem in a nutshell.'

Authors of conventional science education texts usually put expositions of the indeterminacy problem in a very different kind of 'nutshell', such as a stipulative definition of quantum indeterminism or a potted history of the concept's emergence in the work of Werner Heisenberg and Neils Bohr. In my experience, most science educators seem to take it for granted that the textual representation of the indeterminacy problem should in large part be a didactic and synoptic recitation of the ‘facts’ (including the historical ‘facts’) of quantum indeterminacy rather than, as in the passage quoted, embedding the problem in the casual conversation of a novelist’s imaginary characters. But the narrative strategies of fiction may be more appropriate for representing many key aspects of science to learners than the expository textual practices that have dominated science education to date. This is not only because fictional narratives may be more ‘accessible’ (that is, less boring) to many learners than the language of textbooks but also because the narrative structures of some forms of literary fiction are better suited to expressing and exploring the concepts and methods of postmodern science (and, indeed, modern science as it is now being reinterpreted).

Fact, fiction and ‘reality’

Science education is one of a number of educational discourses and practices in which it is assumed that reliable (intersubjective) distinctions can be made between ‘fact’ or ‘reality’ on the one hand and ‘fiction’ or ‘imagination’ on the other. In part this may be because the storytelling practices commonly adopted by both scientists and science educators reflect what Sandra Harding (1986: 193) calls ‘the longing for “one true story” that has been the psychic motor for [modern] Western science’. This longing for ‘one true story’ has driven the construction of narrative strategies in which fact and fiction are mutually exclusive categories, facts are assumed to correspond with ‘truth’, and ‘scientific facts’ are equated with a ‘reality’ that is represented as being independent of human agency.

But fact and fiction are much closer, both culturally and linguistically, than these narrative strategies imply. A fiction, in the original sense of fictio, is something fashioned by a human agent. The etymology of ‘fact’ also refers to human action; a fact is the thing done, ‘that which actually happened’, the Latin factum being the neuter past participle of facere, do (OED). Thus, both fact and fiction refer to human experience, but ‘fiction’ is an active form – the act of fashioning – whereas ‘fact’ descends from a past participle, a part of speech which disguises the generative act. Facts are testimonies to experience. Scientific facts are testimonies to the experiences of scientists in actively producing facts with their specialised technologies of data generation and inscription, their rule-governed practices of interpretation, and their characteristic traditions of social relationships and organisation. For example, as Haraway (1989: 4-5) writes:

Biology is the fiction appropriate to objects called organisms; biology fashions the facts ‘discovered’ from organic beings. Organisms perform for the biologist, who transforms that performance into a truth attested by disciplined experience; i.e., into a fact, the jointly accomplished deed or feat of the scientist and the organism.… Both the scientist and the organism are actors in a story-telling practice.

Thus, the opposition of fact and fiction in modern science is a fiction – part of a story which has been fashioned to rationalise the strategies used by modern scientists in producing facts.

Postmodern science: reconnecting fact and fiction

Modern science was constructed on empiricist and experimentalist assumptions. By the middle of the 19th century it had come to be typified by Newtonian physics and (as Newton had foreseen – and deplored) was materialistic, deterministic, atomistic and reductionist. Scientists and educators alike assumed that science was chiefly a matter of patiently seeking the 'facts' of nature and reporting them 'objectively'. The breakdown of this assumption was given impetus by a series of events in the physical sciences that began in the late 1880s. As Joseph Schwab (1962: 198) writes:

The new physics… did not come about because direct observations of space, place, time, and magnitude disclosed that our past views about them were mistaken. Rather, our old assertions about these matters were changed because physicists had found it fruitful to treat them in a new way – neither as self-evident truths nor as matters for immediate empirical verification. They were treated, instead, as principles of inquiry – conceptual structures which could be revised when necessary, in directions dictated by large complexes of theory, diverse bodies of data, and numerous criteria of progress in science.
Today, almost all parts of the subject-matter sciences proceed in this way. A fresh line of scientific research has its origin not in objective facts alone, but in a conception, a deliberate construction of the mind. On this conception, all else depends. It tells us what facts to look for in the research. It tells us what meaning to assign these facts.

In effect, Schwab is describing the emergence of postmodern science – the realization that many of the perceptions, interpretations and explanations that constitute 'reality' and our experience of it are not 'facts' (as modern science conceived them) but meanings fashioned by human agents: that is, they are fictions. 'Science' and 'fiction' do not exist in separate domains but are culturally interconnected. This is not simply a matter of science and literature finding common meeting places in science fiction and other forms of expressive art. Nor is it just a matter of scientific theories being translated into literary themes, a practice which long preceded the emergence of science fiction as a distinctive literary mode (for example, Copernican cosmology permeates the poetry of John Donne and concepts of disease formation are a distinctive feature of Emile Zola's novels). As Hayles (1984: 10) demonstrates, 'literature is as much an influence on scientific models as the models are on literature', insofar as there is a two-way traffic in metaphors, analogies and images between them. The narrative strategies of fiction are not unknown in science. In the 1930s Albert Einstein defended realism and relativity against the paradoxical truth claims of quantum mechanics by means of a 'thought experiment' – an experiment which so 'obviously' had the outcome he wanted that it was not considered necessary for anyone actually to perform it.

Einstein's strategy was persuasive: nearly thirty years elapsed before other physicists went to the trouble of uncovering his unstated assumptions and used them to predict the outcomes of feasible experiments which could be compared with the outcomes predicted by quantum mechanics. Many physicists interpret the results of these experiments as being decisively in favour of quantum mechanics. But I am less concerned here with whether or not Einstein was 'right' than with the narrative strategy he used to exercise discursive authority in the community of physicists. In effect, Einstein sustained doubt in the explanatory power of quantum mechanics (for many years and among many colleagues) with no more and no less than a 'thought experiment' – a plausible story, a science fiction.

Science, literature and poststructural criticism

In recent years, the deep cultural connections between science and literature have been most clearly elucidated through the discourses of poststructural criticism. While poststructuralism is most obviously applicable to literary theory, the cognate interests of postmodern scientists (especially those working in the new chaos sciences) have established poststructural critical discourses as fertile sites for discussing and investigating both scientific and literary cultures and the transactions between them (see also Hayles 1990, 1991).

Poststructural criticism is concerned with the problems posed by metanarratives – stories that purport to describe, explain or provide a foundation for other stories, including analytical systems which are presumed to offer 'objective' or grounded perspectives on the 'real' world. For example, positivism is a metanarrative – a set of rules characterising positive knowledge. The positivist story makes rules for other stories from categorical distinctions between analytic and synthetic, linguistic and empirical, observation and theory, and so on. The poststructural position is that a metanarrative is just another narrative, a social agreement constructed by participants in a particular discourse. The positivist metanarrative has for the most part been abandoned by postmodern scientists in practice – but it persists in the rhetoric of many scientists and in the discourses and practices of science education. As presently constructed, the language of science education privileges modernist scientific discourse as the means of making and telling 'one true story'. If science education is to have any correspondence or compatability with postmodern science, science educators may need to adopt the skepticism towards metanarratives that characterises poststructural discourses. Science education might then reflect the kind of understanding of 'reality' that is encapsulated in the words of a poster I once saw in an English (language) classroom: 'the universe is not made of atoms – it is made of stories'. Presenting students with a drawing of the Bohr-Rutherford model of the atom as if it truthfully represented some small segment of the 'real' universe is nonsensical given that it is an abstraction as far removed from a learner's experiential knowledge as it is from scientists' understandings of quantum indeterminacy. The 'truth' and 'reality' of the Bohr-Rutherford model of the atom is that it is one aspect of a story in which data were produced,

inscribed and interpreted by particular people with particular motives and values who worked within a particular social and political context and, furthermore, that this story has in turn generated metaphors and cultural myths which are still affecting society in various ways (not least among them being the myth that being able to recognise, reproduce and/or label a drawing of the model is a significant indicator of one's achievement in 'learning science' in schools).
The insights which can emerge from treating science as a storymaking and storytelling practice are exemplified by Haraway's critical history of primatology, Primate Visions. Haraway (1989: 4-5) elucidates the ways in which primatology's storytelling practices 'structure scientific vision' and inform the construction of other cultural myths:

… monkeys, apes, and human beings emerge in primatology inside elaborate narratives about origins, natures, and possibilities. Primatology is about the life history of a taxonomic order that includes people. Especially western people produce stories about primates while simultaneously telling stories about the relations of nature and culture, animal and human, body and mind, origin and future. Indeed, from the start, in the mid-eighteenth century, the primate order has been built on tales about these dualisms and their scientific resolution.

Many of these 'narratives about origins, natures, and possibilities' are sustained by literary and other fictions and part of Haraway's method is to 'read' primatology 'as science fiction, where possible worlds are constantly reinvented in the contest for very real, present worlds':

I am interested in the narratives of scientific fact – those potent fictions of science – within a complex field indicated by the signifier SF… a complex emerging narrative field in which the boundaries between science fiction (conventionally, sf) and fantasy [have become] highly permeable in confusing ways, commercially and linguistically'… [SF represents] an increasingly heterodox array of writing, reading, and marketing practices indicated by a proliferation of 'sf' phrases: speculative fiction, science fiction, science fantasy, speculative futures, speculative fabulation'…
SF is a territory of contested cultural reproduction in high-technology worlds. Placing the narratives of scientific fact within the heterogeneous space of SF produces a transformed field. The transformed field sets up

resonances among all of its regions and components. No region or component is 'reduced' to any other, but reading and writing practices respond to each other across a structured space. Speculative fiction has different tensions when its field also contains the inscription practices that constitute scientific fact.

The final chapter of Primate Visions alternates between 'reading primatology as science fiction' and 'reading science fiction as primatology'. Haraway (1989: 370) reasons that:

Mixing, juxtaposing, and reversing reading conventions appropriate to each genre can yield fruitful ways of understanding the production of origin narratives in a society that privileges science and technology in its constructions of what may count as nature and for regulating the traffic between what it divides as nature and culture.

Primate Visions testifies to the potential effectiveness of SF in helping to deconstruct and demystify contemporary orthodoxies – in this case, the social, textual and material history of primatology. Clearly, SF has mediated Haraway's own learning in important ways. The kind of learning that Haraway models in Primate Visions is as applicable to school science education as it is to research in the history and philosophy of primatology. In my experience, school students require little encouragement to mix and juxtapose the narratives of 'scientific fact' with the narratives of science fiction. Indeed, they may be more willing than their teachers to mix and juxtapose seemingly disparate elements of these narratives in critical and creative ways. The difficulty for science teachers may be that many have cast themselves as 'defenders of the faith' – defenders of the privileged status of modern science – rather than as 'understanders' (connoisseurs and critics) of the myths, narratives and rituals which constitute science in the contemporary world.

SF and science education

SF often registers new scientific knowledge long before it is recognised by the general public – and even longer before it is registered in textbook science. For example, in The Time Machine, H.G. Wells (1895) acknowledges the existence of non-Euclidean geometries and suggests a relationship between space and time that appears, in retrospect, to anticipate the Einstein-Minkowski notion of a space-time continuum. Wells was clearly abreast of the scientific debates of his era and the Time Traveller's opening remarks include an assertion that remains pertinent to this day: 'The geometry… they taught you at school is founded on a misconception'. The limitations of Euclidean geometry were well-known to nineteenth century mathematicians yet, nearly a century later, few school children have been taught that Euclid's geometry is only one among many. By the late nineteenth century there was growing interest among mathematicians in the abstract geometry of four (and more) dimensions yet this was not reflected in popular or school texts. As Richard Costa (1967: 32) writes: 'For a generation yet to hear of Albert Einstein, the opening pages of The Time Machine provided an introduction to the possibilities of the Fourth Dimension which in 1895 was not elsewhere available outside scientific journals'.

Many accounts of the relationship between 'real' science and SF are overly concerned with demonstrating the wisdom of their own hindsight. For example, in The Science in Science Fiction, Peter Nicholls (1982) catalogues the various ways in which particular works of SF can be seen, in retrospect, to have accurately predicted developments in science and technology; he is also concerned to demonstrate 'where science fiction gets it wrong' (Nicholls 1982: 190). But from the point of view of science education, it may be more important to attend to the subject matters about which SF speculates than to the accuracy or otherwise of its predictions. As I have argued elsewhere (Gough 1992a, in press), one of the purposes of science education is to represent science as a form of knowledge in the curriculum. Lawrence Stenhouse (1975: 85) provides a useful description of what such a representation entails:

… a form of knowledge has structure, and it involves procedures, concepts and criteria. Content can be selected to exemplify the most important procedures, the key concepts and the areas and situations in which the criteria hold.
Now it might be thought that this is to designate procedures, concepts and criteria as objectives to be learned by the students. This strategy… would, I believe, distort the curriculum. For the key procedures, concepts and criteria in any subject – cause, form, experiment, tragedy – are, and are important precisely because they are, problematic within the subject. They are the focus of speculation, not the object of mastery.

Many of the concepts that are 'problematic' and 'the focus of speculation' in science at any given time cannot be found in the textbook science of the day – but it is more than likely that they will be among the foci of speculation incorporated into contemporaneous works of SF. Thus, for example, part of the educative value of The Time Machine in its day was that it gave imaginative form to concepts that were deeply problematic and key foci of speculation among late-Victorian scientists and mathematicians, such as the space-time relationship, entropy and evolution – concepts that were not addressed by schooling at the time. In a similar fashion, much of the textbook science of today is concerned with the kind of subject matter that is amenable to being treated as an 'object of mastery', such as stipulative definitions and relatively secure and stable propositions and 'laws'. It is left to science journalism and SF to provide public access to the problematic concepts which are presently the foci of speculation for many working scientists. Outside of the journals in which reports of current scientific research are published, science journalism and SF are key sites for exploring the conceptual territories that mark out the 'leading edges' of science, whereas textbook science seems chiefly to be concerned with the trailing edges of scientific inquiry.
A recent example of SF embodying the leading edges of scientific speculation is provided by the emergence of chaos theory as a theme in SF. As developed by Belgian thermodynamicist Ilya Prigogine during the 1960s and '70s, chaos theory explains how complex, far-from-equilibrium systems spontaneously transform themselves into new levels of complex organisation. Prigogine's model of self-organising systems as 'dissipative structures' appears to reconcile a number of deeply problematic contradictions in twentieth century science, including the very different models of physical function provided by entropy versus evolution, and the different roles and

attributes of time in microscopic physics and macroscopic biology. The profound cosmological implications of Prigogine's work were quickly recognised and he received the Nobel Prize for chemistry in 1977. However, his work was not published in English in any popular form until 1984 when Order Out of Chaos (Prigogine and Stengers 1984) was translated from the French. Some SF writers seized very quickly upon Prigogine's work, one of the earliest being A.A. Attanasio (1981) whose novel, Radix, incorporated some of Prigogine's key ideas some years before they were popularised in English.

Prigogine's thinking has promoted highly original interdisciplinary work in astrophysics, biology, biophysics, chemistry, ecology, economics, education, management, neurology, particle physics, thermodynamics and traffic studies, but it has had little or no effect on 'textbook science' and school science curricula. Nevertheless, many of Prigogine's ideas and their applications can be accessed immediately through SF.

For example, in the graphic novel Watchmen (Moore et al 1987), a dark satire on superhero mythologies and American politics, one central character is the aptly named Dr Manhattan, a towering, blue-skinned physicist with superhuman qualities. Dr Manhattan is the reincarnation of a nuclear scientist who is materially 'deconstructed' when he accidentally is irradiated by subatomic particles. The novel's representation of the scientist's reconstruction involves two intertwining – and contradictory – metaphors. One metaphor is borrowed explicitly from Einstein's rueful reflection on his role in the release of atomic energy: 'if only I had known, I should have become a watchmaker'. The scientist repairs a friend's watch a short time before his demise and his reconstruction is depicted as 'just a question of reassembling the components in the correct sequence'. But other visual and verbal cues (not all of which are apparent in the sequence shown here) suggest that his transformation can itself be conceived as a metaphor of chaos. That is, the scientist's disassembled particles can be interpreted as a chaotic system, a dissipative structure which spontaneously reorganises itself at a higher level of complexity represented by Dr Manhattan's superhuman powers (see exhibit 8: Dr Manhattan: order out of chaos?). Thus, Dr Manhattan's ambiguous genesis can be seen to symbolise the contesting paradigms of modern and postmodern science – of deterministic mechanics (Newton's 'clockwork universe') versus the unpredictable dynamics of chaotic self-organising systems.

Another novel which incorporates chaos theory in significant ways is Lewis Shiner's (1988) Deserted Cities of the Mind. The central character, Thomas, is an anthropologist investigating 'the application of Ilya Prigogine's dissipative structures to the Mayan collapse, circa 900 a.d.' (Shiner 1988: 24). Prigogine's theories provide numerous images and metaphors throughout the story. In a key passage (Shiner 1988: 146-7), Thomas throws pebbles into a pond beneath a waterfall:

The turbulence made them dance, two steps to the right, up for a second, then spinning off sideways and down. Waterfalls were very big in Chaos Theory, of which Prigogine's and Thomas' own work were just a part.

According to classical physics the patterns should be predictable, because everything that went into them was quantifiable. Volume of water, depth of streambed, angle of gradient, everything. But the patterns were like living organisms, influenced by their own history and their reactions to each other, and they could never be nailed down.
What does this tell us, he thought?

This unanswered question exemplifies some of the speculations of contemporary chaos scientists. As contextualised in this particular story, it is a question equally open to conjecture by learners in school science education. At the moment, such stories are one of the few ways in which the characteristics and possible implications of chaos theory can be explored by young learners. Furthermore, distinctions between ‘fact’ and ‘fiction’ are irrelevant to considering the above passage’s merits as a ‘focus of speculation’. Indeed, embedding chaos concepts in an explicit fiction (rather than in the fiction that masquerades as fact in science textbooks) may make it easier for teachers and learners alike to treat the concepts as foci of speculation rather than as objects of mastery.

Chaos and narrative complexity

In the past we have always assumed that the external world around us has represented reality, however confusing or uncertain, and that the inner world of our minds, its dreams, hopes, ambitions, represented the realm of fantasy and the imagination. These roles,… it seems to me, have been reversed. The most prudent and effective method of dealing with the world around us is to assume that it is a complete fiction…
We live in a world ruled by fictions of every kind – mass-merchandizing, advertising, politics conducted as a branch of advertising, the instant translation of science and technology into popular imagery, the increasing blurring and intermingling of identities within the realm of consumer goods, the pre-empting of any free or original imaginative response to experience by the television screen. We live inside an enormous novel. (Ballard 1974: 8)

Postmodern science suggests that ‘reality’ is much more complex than modernist scientific accounts reveal. The narrative complexity required to formulate and problematise the realities inferred by quantum mechanics and chaos theory cannot be found in the reductionist language of modern science. Narrative strategies that are appropriate to the complexities of a chaotic phenomenal world are more likely to be modelled by literary fiction than by the ‘factual’ narratives of conventional scientific discourses.
For example, one aspect of chaos theory, the so-called ‘butterfly effect’, suggests that very small perturbations in natural systems can have very large consequences (a butterfly flapping its wings in Werribee can cause a hurricane in Hawaii). This principle is a commonplace of fictional narrative and, as Porush (1991: 381) argues, in this respect chaos theory corresponds with the worldview of Dickens, Shakespeare and every other novelist and dramatist ‘for whom small accidents send the hearts of mortals and their fates wheeling out of their appointed Newtonian orbits into grand

twists of fate and destiny'. Such a view of human experience, like the butterfly effect in global climatic phenomena, cannot be accommodated by modern science. Newton's reductionist 'world machine' was – and to some extent still is – seen by many people as a 'common sense' view of reality, yet the common and sensible (but irreducibly complex and indeterminate) events of everyday life and the global biosphere cannot be represented by Newtonian mechanics. Newton's world, in which reactions are reversible and interactions reduced to a few simple algorithms, seems like a crude science fictional space – a minimalist abstraction from a thought experiment not

unlike Edwin Abbott's nineteenth century novel Flatland. Indeed, Newtonian mechanics is at its most plausible in such fictional worlds – for example, the formula determining force by reference to mass and acceleration ($F=ma$) is best demonstrated in frictionless space. By contrast, the world described by chaos theory is recognisably sensible – a world in which 'nature' and 'reality' are, as it were, speaking the same language as the great mimetic artists.

Paradoxically, science textbooks are already like mimetic novels in some respects, despite the fiction of their differences and despite each being characterised by very different narrative strategies. Both kinds of text sustain the illusion that they do not mediate between reader and an exterior world but, rather, that they are offering transparent windows onto that world. A key difference is that the authors of mimetic texts usually are conscious of their own artistry in sustaining the reader's belief in the verisimilitude of the world 'revealed' by the text, whereas authors of science textbooks seem to believe that they are constructing a neutral transmitter of 'reality' to the reader. But a poststructural approach to the representation of a chaotic phenomenal world in a text requires that the text draws attention to its own structures and properties as a chaotic generator of meaning and significance. In literary criticism, such a text is known as a metafiction, a form of writing which, as Patricia Waugh (1984: 2) writes, 'draws attention to its status as an artefact in order to pose questions about the relationship between fiction and reality'. A science education text should aspire to no less: it, too, should pose questions about the relationship between the stories constructed by scientists and the reality they purport to describe and explain. In other words, a science education text should provide a critique of its own methods of construction, not only to lay its own structures and assumptions bare, but also to explore the fictionality (the social constructedness) of the world outside the text.

Conclusion: Cyberantics revisited

Prosser's (1992) Cyberantics is, of course, a metafiction. It is also an educative text in the conventional sense: many of Prosser's 'annotations', such as those dealing with the structure, function, social organisation and communication processes of ants, would not be out of place in a standard science textbook or in the kind of synoptic or encyclopedic resource materials to which primary school students are often referred when they are 'doing ants' as a topic. But Cyberantics does much more than a conventional science text. For example, the spoof biography of Mayakovsky (in which we learn, for example, of his disastrous dabblings in VAI – Viral Artificial Intelligence), presented as an Afterword, raises many questions about the conduct of scientific research, the nature of human, animal and artificial intelligence, the social organisation of scientific labor and the reconstruction of scientific knowledge for public consumption. Also, by being cast within the conventions of a children's talking animal story, Cyberantics invites the reader to bring to bear on the text the wide range of cultural meanings associated with this literary mode, such as mocking and subverting the modern scientific practice of maintaining clear distinctions between humans and other beings.

More importantly for the argument presented here, as a metafiction Cyberantics functions as a complex system generating multiple interpretations – in other words, it displays the properties of what science calls chaos. Thus, it explores and illustrates, in a form accessible to children and adults alike, an important correspondence between postmodern science and literature. As Peter Stoicheff (1991: 85) writes:

metafiction and scientific chaos are embraced by a larger revolution in contemporary thought that examines the similar roles of narrative, and of investigative procedure, in our 'reading' or knowledge of the world.

Cyberantics is a model of what a postmodern science education text could be. It embeds stories of modern science, a delightful children's story and a satire suitable for both children and adults within a complex and complicating metafiction that exemplifies a worldview shared alike by postmodern science and poststructural critical discourse – a worldview in which, as Stoicheff (1991: 95) writes, 'the world is a text that is read, and our interpretation of our world is a function of our reading of texts'.

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Ari is the Japanese word for ‘ant’

Cyberantics is a temporally ambiguous text. The annotated edition is clearly dated 1992 but Prosser’s (1992: 54) bibliography cites the first edition as being published (by Jiffy Books, New York) in 2172. Prosser (1992: 53) also refers to events which took place as late as the year 2197. However, as Le Guin (1985: xi) points out, the difficulties of translating (and, by implication, publishing) a text that has not yet been written may have been exaggerated: ‘The fact that it hasn’t yet been written, the mere absence of a text to translate, doesn’t make all that much difference… All we ever have is here, now’.

‘When asked why an ant needs to be equipped with a miniaturised cold plasma laser, Mayakovsky answered: ”I’d want one”.’ (Prosser 1992: 30).

To Grumet’s ‘collective’ I would add selective

See Gough et al (1991)

See also Gough (in press)

According to Prosser (1992: 52), Mayakovsky’s rejoinder to questions about the validity of his mode of presentation was: ‘Who wants to read a journal when you can have fun?’

As Donna Haraway (1989: 5) writes: ‘To treat a science as narrative is not to be dismissive… But neither is it to be mystified and worshipful in the face of a past participle.’

For further details of this story see McCusker and McCusker (1988)

For a more detailed discussion of the narrative strategies found in science and science fiction see Broderick (1989) and Ormiston and Sassower (1989)

I also endorse another possibility: SF = serious fun

For further details of the science and mathematics of The Time Machine see Geduld (1987)

For a more detailed discussion of the links between chaos and SF see Porush (1991)

Well known examples of metafictional novels range from Laurence Sterne’s Tristram Shandy to such contemporary works as John Fowles’s The French Lieutenant’s Woman, Umberto Eco’s The Name of the Rose, Ursula Le Guin’s Always Coming Home and many books by John Barth, Donald Barthelme, Richard Brautigan, Robert Coover, Doris Lessing, David Lodge, Tom Robbins and Kurt Vonnegut

See Gough (1990) and Le Guin (1987) for a more detailed discussion of children’s talking animal stories and their significance