# The manufacture of aluminium and the rubbish-pickers of Rio: building interlocking narratives

*Ralph Levinson*

ABSTRACT Treating the processes of science and its social effects as a series of interlocking narratives enables learners to see science as a system. This article draws on the chemistry of the manufacture of aluminium to illustrate links to social justice, economics, environmental protection and employment. By drawing on stories of the main actors in this process it is possible to discover connections between seemingly disparate events. Examples are given of how these narratives can be used in citizenship and science lessons.

Everyone enjoys a good story. If this aphorism holds true, stories ought to be a valuable tool in stimulating interest in science. I was going to add 'in young people at school', but if everyone loves stories then they are capable of inspiring engagement in science from the nursery to the nursing home.

The earliest stories are associated with the first records of belief systems, sagas, fairy tales and myths. Children, and adults, come to understand the mores of a culture and learn morality by seeing what comes about in consequence of being humble, proud, rebellious, curious, kind or nasty. It is that sense of relaying experience that has come to be seen as a powerful tool in subject teaching. Humanities and the arts have long deployed narrative stories because their subjects are the human condition and human experience. But for science, where the core concepts are such things as electromagnetic fields, photosynthetic systems and chemical reactions, the role of the story is more challenging: these entities lack the psychological insights and serendipitous turns of being human. Nonetheless, writers and educators have taken science by the scruff of the neck and turned scientific episodes into stories with protagonists, motives, moral evaluations and plots.

Narratives within the modern literary canon increasingly have science as their central theme. *Copenhagen*, a play by Michael Frayn, focuses on the tension between Bohr and Heisenberg as each endeavours to discover the other's intentions with regard to the development of the atomic bomb during the Second World War. The core ideas of quantum theory are intertwined with their political, personal and social consciousnesses in the developing narrative of Bohr and Heisenberg's relationship. Italo Calvino employs scientific concepts such as subatomic structure and natural selection in his book of short stories, *Cosmicomics*. These stories reflect the spectrum of human relationships, as in quarks compressed within a single point before the Big Bang, and land animals puzzled at the archaic ways of their water-dwelling ancestors. In *The life of Galileo* by Bertolt Brecht, Galileo's evidence in support of the Copernican heliocentric system is the focus of conflict between science and the Catholic Church. But it is seminal scientific works that have produced some of the greatest narratives, such as *On the origin of species*, where Darwin creates a '*story of the world*' (Beer, 2000).

The use of stories in teaching and learning science is taken up in the *Beyond 2000* report (Millar and Osborne, 1998), which recommends:

> *that science education should make much greater use of one of the world's most powerful and pervasive ways of communicating ideas – the narrative form – by recognising that its central aim is to present a series of 'explanatory stories'. By this we mean that science has an account to offer in response to such questions as 'How did*

*we catch diseases?', 'How old is the Earth and how did it come to be?' ... we want to emphasise the value of the narrative in communicating ideas and in making ideas coherent, memorable and meaningful.* (p. 2013)

Examples of 'explanatory' stories are the 'Particle model of chemical reactions' and 'The Earth and beyond'. They tell of a series of events explaining macro-phenomena, for example the dissolving of salt in water as the interaction between ions from the salt and water molecules. There has been criticism of the way in which these accounts attempt to explain materialistic causations but exclude the human richness of stories (Solomon, 2002). Anthropomorphising scientific entities has been proposed; while this might stimulate interest in primary school children, such an approach can be seen as patronising by secondary school students (Rowcliffe, 2004).

Ogborn *et al.* (1996) likened effective explaining in science to a story because stories explain '*how something comes about*' (p. 9). So, '*stuff*' seems to disappear when mixed with water because of interactions between the water molecules and the solute. These stories have a dramatis personae of protagonists, which interact to enact events producing consequences called phenomena, such as the pollution of water courses. Hence, fertilisers provide plants with essential nutrients, the rain washes the fertilisers into rivers, the fertilisers enhance the proliferation of algae, and there is a consequent reduction of the oxygen dissolved in water and a threat to other forms of freshwater life. In his pamphlet on narrative, Harold Rosen points to the ways in which the structure of the narrative story is instrumental in understanding science:

*What is geology but a vast story which geologists have been composing and revising throughout the existence of their subject? Indeed what has the recent brouhaha about evolution been but two stories competing for the right to be the authorized version, the authentic story, a micro-narrative? ... How do we understand foetal development except as a fundamental story in which sperm and ovum triumph at the denouement of parturition? Every chemical reaction is a story compressed into the straitjacket of an equation.* (Rosen, 1987: 16)

In this article I want to demonstrate that stories are indispensable when it comes to understanding science in its social context. I will use the idea of interlocking narratives to explain how core scientific concepts do not exist in a social vacuum, but have broad ramifications that incorporate concepts of social justice such as human rights and the right for labour to organise, opening up channels for the voices of the marginalised:

*Narrative art has the power to make us see the lives of the different ... with involvement and sympathetic understanding, with anger at our society's refusal of visibility. We come to see how circumstances shape the lives of those who share with us some general goals and prospects.* (Nussbaum, 1997: 88)

## The story of aluminium: the background

I will exemplify the idea of interlocking narratives with the story of the industrial manufacture of aluminium. My reason for doing this is that a straw poll of teachers and students revealed the extraction of metals as one of the most boring topics teachers have to teach and students have to learn. The extraction of aluminium lends itself particularly well to my argument because it draws together stories from different parts of the world with diverse concerns and motivations, interactions between powerful global interests, world demand for valuable resources, and disparities of wealth.

Aluminium is vital to world and national economies and we come across it every day in our lives. Its refractory properties and low density make it an excellent wrap for cooking food at high temperatures and for take-away food in trays. It is durable and therefore important in the manufacture of relatively cheap bikes (titanium is also light but stronger and more expensive to produce) and cars with low fuel consumption, as well as in the aircraft industry. It is also used on a vast scale in the manufacture of soft drinks cans. Because it was so difficult to extract aluminium in the nineteenth century it was extremely expensive, far more expensive than gold, and to demonstrate his wealth Napoleon III used aluminium cutlery, in preference to gold, at state banquets.

The equation for the reduction of aluminium ions during electrolysis is:

$$Al^{3+} + 3e^{-} \rightarrow Al$$

In other words, three times as many moles of electrons (or three times the quantity of electricity) are needed to produce one mole of aluminium atoms, compared with, say, an equivalent amount of sodium or potassium. This equation, and the few symbols within it, can explain many socio-political and environmental effects.

From its position high up in group 3 of the Periodic Table, the aluminium atom is relatively small and its highly positively charged ion even smaller, which means that there are large electrostatic forces holding the aluminium and oxide ions together in alumina, $Al_2O_3$, in which aluminium is found combined with oxygen before smelting. Alumina (aluminium oxide), therefore, has a relatively high melting point compared with most other metal-containing compounds. Alumina must be prepared in a molten state for electrolysis, but the temperature needed is so high that it is fused with the mineral cryolite, sodium aluminium fluoride ($Na_3AlF_6$). Cryolite is inert and does not affect the chemistry of the electrolysis but, in the high-temperature conditions of the smelter, powerful greenhouse gases called perfluorocarbons are released into the atmosphere as a result of the combination of the halogen content of the cryolite with the graphite electrodes.

During the 1970s, when the price of oil escalated, many manufacturers moved to the use of hydroelectricity instead of oil-burning power stations. The problem with hydroelectricity is that it needs the potential gravitational energy of water falling from a great height. Thus hydroelectric power stations often have to be sited in areas of great natural beauty where there are high mountains and copious supplies of running water in the form of fresh-water rivers (Box 1). In hydroelectricity production a great deal of energy is transferred, which raises the temperature of surrounding water sources, with a drastic effect on the viability of the existing fauna.

Every stage in the manufacture of aluminium can result in some form of spoliation and pollution:

- excavation of the bauxite;
- shipping the bauxite;
- purification of alumina from the ore in the Bayer process, which can leave red mud and toxic lakes of caustic alkali around the smelter, affecting the local water table (the chemistry of the amphoteric aluminium oxide has a role here); there are methods for clearing up red mud but these processes leave an environmental footprint;
- production of carbon dioxide as the graphite anode combusts during the electrolysis;
- generation of fluorocarbons from the cryolite and the electrodes.

Offset against this physical and social cost is the benefit in terms of employment and investment in the local economies by producers and processors, and the manufacture of a commodity of high global utility.

## Enter the *catadores de lixo*

About ten years ago I was travelling with some Brazilian friends on the outskirts of Rio de Janeiro when I saw hundreds of people, young and old, congregated around massive rubbish dumps. These were the *catadores de lixo*, literally the rubbish pickers, who scavenge the streets of Brazilian towns and cities for empty aluminium drinks cans and bring them to the dumps where the cans are taken away for reprocessing. The *catadores* receive remuneration based on the quantity of cans they collect.

Brazil is a country of huge social and economic discrepancies: extremely wealthy people and very poor people often live in the same cities, and many of the latter have to scavenge to

**BOX 1 Examples of the use of hydroelectricity to manufacture aluminium**

- The proposal to build a dam and smelter in the wilderness of the eastern Icelandic highlands (see ‘Have your say: Iceland’s dilemma’, http://news.bbc.co.uk/1/hi/programmes/crossing_continents/6471839.stm, accessed February 2008).
- An Alcoa-led consortium bid to use the Barra Grande dam in south-east Brazil, resulting in the deforestation of Brazilian pine on the Atlantic coast (see ‘Push to block Brazil dam project’, http://news.bbc.co.uk/1/hi/sci/tech/4146325.stm, accessed February 2008).
- Noranda’s proposal to build a smelter in the Chilean rainforest (see ‘Canadian industrial giant prepares invasion of Patagonia’, http://www.nativeforest.org/action_alerts/alumysa_8_29_02.htm, accessed February 2008).

survive. Wealthy Brazilians tend to be profligate and in some ways this works to the advantage of the *catadores*, who use the cans thrown on the street as their source of income. But life for the *catadores* can be unpleasant: violence among competing gangs of *catadores* leaves the weak, very young and elderly, vulnerable to harm.

Take the case of Maria Cristabel, a 12-year-old girl standing on the festering Rio rubbish heap I passed that afternoon, picking up some money for the hours spent in foraging for cans. Maria lives in a cardboard *favela*, has never been to school and lives with four younger siblings and her parents. A fortuitous change in government policy promises a glimmer of hope in Maria's life and the lives of the *catadores de lixo* as a whole. Seeing the enormous potential for recycling, together with fluctuations in the global prices of raw aluminium, the national and local governments start to work with gang leaders in rationalising and unionising the *catadores*. They are now paid for the number of cans collected, but deals are struck which protect the most needy so that all *catadores* in a particular area receive some income. The Brazilian authorities begin to see the promise of this deal. Large manufacturers of aluminium, such as Alcan, enter into recycling deals with the government, which in turn provides some improvements in the quality of life, such as housing. Children like Maria now have the opportunity to attend school, although there are reports of children being bullied for their illiteracy and denigrated because they come from a family of *catadores*. The government has recognised that the *catadores* have a right to health care and education.

This strategy by the government works. Within a few years Brazil moves from being one of the most wasteful societies to the second biggest aluminium recycler after Japan. But the effects are global. A huge increase in the recycling of cans will result in a lowering of demand for manufactured aluminium. This can be seen to have both benefits and drawbacks. The benefits are potentially less damage to wildernesses and sites of natural beauty. But in the smelters in Jamaica, for example, reduction in demand can mean reduction in labour value and lay-offs. The Jamaican economy has not grown or sufficiently diversified, and there is not enough investment to clear up the local pollution caused by the alkali lakes (Mitchell, 2006).

Of course, the improvements in living conditions for the Maria Cristabels and the *catadores de lixo* in general cannot be responsible for the problems in Jamaica. That would ignore policy making, the ways in which poor countries are beholden to powerful companies and global fluctuations in world markets. My point is that there are interconnections between events (Figure 1) and a worker in Jamaica is linked to a child rubbish-picker in Rio through the quantity of electrical charge needed to reduce aluminium ions.

As a rider, it is important to recognise that this is not necessarily a case of recycling being non-polluting and manufacture always resulting in spoliation. There are always costs and benefits involved. For example, the process of recycling can incorporate the toxic processes of stripping and lacquering cans and the energy costs in building and running recycling sites. But there has been a shift in the route of production and employment patterns, with opportunities for low-paid sectors in one part of the world and threats to others.

## Where do stories start?

Stories have protagonists, events and reflections on those events. In the cycle of interlocking events shown in Figure 1, I have chosen to focus on the *catadores* and how events have had an effect on their human rights. But there have also been more general impacts. Protagonists can be anybody or anything: an aluminium ion, a worker in a Jamaican smelter, a seafarer on a boat transporting the ore, and indeed a Brazilian *favela* dweller. The experiences of all these protagonists are interconnected. Once the aluminium ion has been leached out during purification from the bauxite ore and flows under an electrical potential in the giant Jamaican smelter, like so many trillions of other identical ions, it has already made an impact. The alkali used to extract alumina from the bauxite ore diffuses to the water table if not controlled and can affect the lives of residents, environmentalists and wildlife (Miller, Waite and Harlan, 2001). The energy transferred during electrolysis has also had effects but the activities of the *catadores de lixo* mean that there will be need for less energy consumption in this process. What does that mean for industries that extract bauxite? What effect does reprocessing have on manufacture compared with processing raw aluminium? There are clear links between the amount of energy needed to

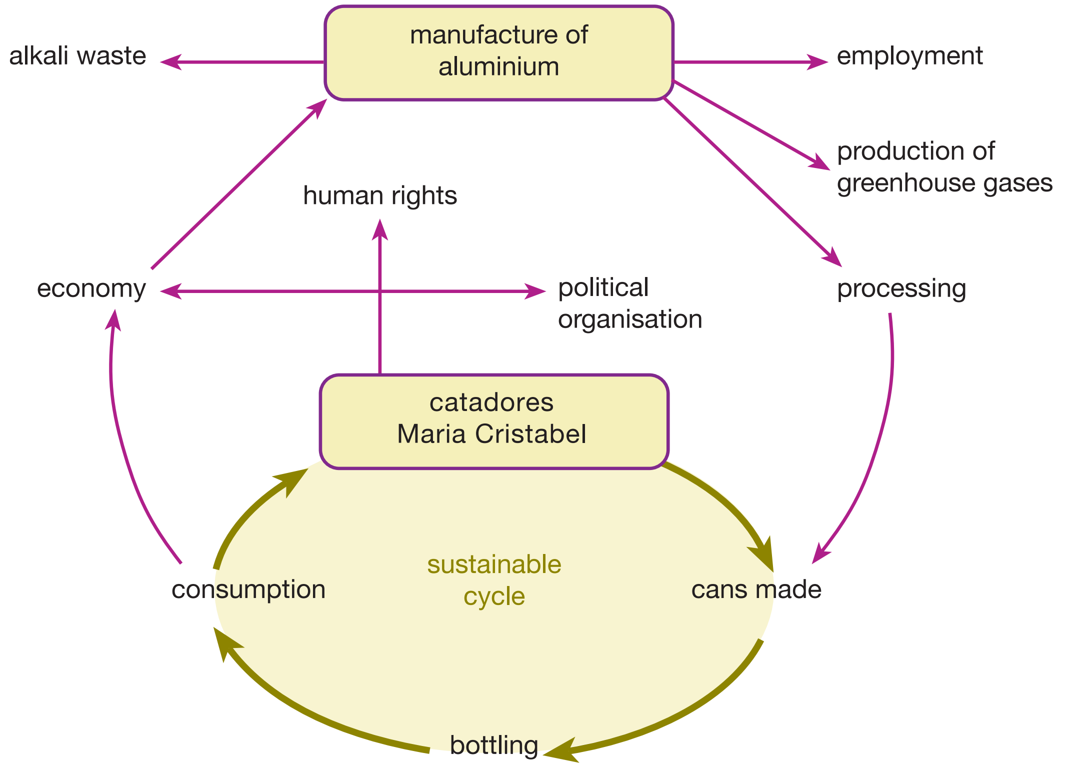


**Figure 1** A cycle of linked events between the manufacture of aluminium and the *catadores de lixo*. Each event is in turn linked to a narrative.

reduce aluminium ions and the realisation of Maria Cristabel's human rights. Each event in the cycle comprises a mini-narrative with links to all the other mini-narratives in the cycle. This cycle itself is linked to other cycles.

This kind of model of interlocking narratives is not, of course, unique to the manufacture of aluminium. All manufacturing processes have interlocking narratives, depending on where you situate the protagonists and the events. You could link an oak tree photosynthesising in an ancient forest to respiration in the liver cell of a local deer, to the smelter in Jamaica and to Maria Cristabel's welfare. There are many stories to tell in these processes and when young people begin to see the links, they can see the implications of the processes they study.

## Conclusion

My purpose is to demonstrate that any scientific process can be conceived as part of a series of interlocking narratives and that, in fact, the science curriculum can be presented as a series of stories or narratives. There are two distinct but related advantages to learning by using this approach. First, stories can reveal the systemic nature of science and enable insight into the big ideas in the discipline. Second, they link the parochial to the global. Other people and other events affect our lives (i.e. those of us living in relative prosperity in the UK): we are dependent on those who may live in distress; human rights and prosperity influence our own immediate concerns; and the great scientific and technological achievements depend on so many diverse contributions.

Telling stories is a strategy to support teachers and learners of science. But there are also clear links with citizenship. For example, a citizenship teacher might emphasise the stories of the *catadores de lixo* in illustrating the links between the state's responsibility to its citizens, social justice and the responsibilities of the manufacturers of aluminium. A science teacher might take the aluminium ion as the central protagonist and show how its fate is linked to the lives of people in different parts of the world and that the choices we make can affect the balance between manufacturing, recycling and cost–benefit analysis.

But there are problems. Including Maria Cristabel in the story I am aware of a certain functionality: Maria Cristabel does not come to life; we do not know how she feels or reacts to the changes in her life. Getting inside Maria's account of what she feels and thinks are central to the narrative account; otherwise she is simply a cipher, a means of carrying a story along, which belies the description of her as a protagonist. I used the example of Maria Cristabel (her name is an alias) because of the feistiness of one 12-year-old girl I met briefly many years ago. The rest of the story is based on reading reports about the *catadores de lixo*. What is important is that we hear and include their stories in their own words.

### References


Beer, G. (2000) *Darwin's plots: evolutionary narrative in Darwin, George Eliot, and nineteenth-century fiction*. Cambridge: Cambridge University Press.

Millar, R. and Osborne, J. (1998) *Beyond 2000: science education for the future*. London: King's College London.

Miller, N., Waite, L. and Harlan, A. (2001) Water resources assessment of Jamaica. Mobile District & Topographic Engineering Center: US Army Corps of Engineers.

Mitchell, D. (2006) JBI: Windalco's mud effluent breaches industry standards. *Jamaica Gleaner*. http://www.jamaica-gleaner.com/gleaner/20060306/lead/lead4.html

Nussbaum, M. (1997) *Cultivating humanity.* Cambridge, Mass: Harvard University Press.

Ogborn, J., Kress, G., Martins, I. and McGillicuddy, K. (1996) *Explaining science in the classroom*. Buckingham: Open University Press.

Rosen, H. (1987) *Stories and meanings*. Sheffield: National Association for the Teaching of English.

Solomon, J. (2002) Science stories and science texts: what can they do for our students? *Studies in Science Education*, **37**, 85–106.


**Ralph Levinson** is senior lecturer in science education at the Institute of Education, University of London. Email: r.levinson@ioe.ac.uk