Engineering Understanding

Sharon Beder, *The New Engineer: Management and Professional Responsibility in a Changing World*. Melbourne: Macmillan Education Australia, 1998. Pp. x + 346. A$84.95 HB, $42.95 PB.

By Sören Törnkvist

In October 1997 four cows on a farm situated on the Halland Ridge in southern Sweden died after drinking water from a nearby stream. The water was contaminated with acrylamid which, it emerged, came from a nearby 10 kilometre railway tunnel construction site. The railway project had been plagued by trouble from the beginning. The Halland Ridge is a 'horst', a heap of earthcrust formed by tectonic forces, with the highest ground water yield of all pre-Cambrian rocks. An attempt to use a huge full-face drill to open up the tunnel failed because the brittle rock of the horst just collapsed.

This should have been no surprise. Past experience from similar constructions in the neighbourhood suggests that drilling makes the groundwater level sink, often well below the limit approved by the Water Board. Gunnar Jacks, Professor of Ground Water Chemistry at the Royal Institute of Technology, Stockholm, says that working in this sort of environment is notoriously difficult.

In an attempt to salvage the project another contractor took over and started to line the inner walls of the tunnel with a two-component material imported from France. The alternative of building a concrete inner ceiling was considered too expensive. The flow of water was, however, such that the individual components were washed away before the composite was formed. One of the components, acrylamid, is known to be carcinogenic. When the water was pumped from the building site it found its way to the stream where the cows had been drinking. It was later shown that the workmen had also been exposed to acrylamid.

In the ensuing debate several scapegoats were named. The most prominent was Swedish Rail, the government-owned company that commissioned the work. Swedish Rail never fully warned the contractor about the geological difficulties in working this sort of rock. It was alleged that this information was suppressed in order to get the project approved and started. Originally the cost estimate was 690 million Swedish crowns. It now might rise to four or five billion Swedish crowns, an increase of a factor of seven.

Had the Hallands Ridge disaster happened before Sharon Beder wrote *The New Engineer,* she might have included it as a case study of how suppressed information can lead to disaster. Not that Beder's book lacks empirical foundation—but this recent example shows how history repeats itself even in (relatively) 'environmentally-friendly' Sweden. And it demonstrates the urgency of Beder's book.

The New Engineer is divided into three parts. Part One, Engineering—Past and Present, deals with issues from Science and Technology Studies. Its principal theme is design as an engineering ideal and the problem of separating design from context. There is also a short discussion about the philosophy of engineering which refers to Popper's *Conjectures and Refutations* and Kuhn's *The Structure of Scientific Revolutions*. This discussion rather confuses the issue, since Popper and Kuhn only concern themselves with 'science', whereas Beder's main contention is that science only partially overlaps engineering. (Kuhn has commented that the concept of applied science is cumbersome.) Don Ihde's important work on the philosophy of technology, especially his *Philosophy of Technology: An Introduction,* (1993), would have been more useful.

Beder also discusses the difficulties inherent in making engineering education excessively scientific. Historically, this was driven by an urge to increase the status of university-educated engineers *vis-à-vis* the older engineers from the 'shop culture'. Beder refers to W.J.M. Rankine's attempt to create 'engineering science' following a dispute over the teaching of the theoretical principles of technology. According to the research of Svante Lindqvist, Professor of the History of Technology at the Royal Institute of Technology in Stockholm, there was also a substantial inferiority complex among engineers *vis-à-vis* academe. This can in part explain the obsession in engineering schools with mathematical and scientific subjects, mostly taught out of context and often used as hurdles to further studies.

Part Two is an extended case study of the sewerage systems of Sydney from early 1800 up to today. I found this part of the book most interesting. It forms a coherent narrative and Beder knows her story well. It illustrates the complex mutual interactions between technical fixes, economy,

people's craving for comfort and the occasional concern about the environment when faeces are washed up on the beach. Whereas the text in Parts One and Three gets a bit heavy, Part Two is easy reading and deserves wide readership.

In Part Three, the hot issues of engineering ethics are discussed. Beder's discussion is low-key. Rather than lamenting the failings of engineers, she stresses the positive attempts made in the form of legislation and ethical rules adopted by engineering societies. I find her discussion of 'expert authority' particularly interesting where she analyses the tensions between self-appointed experts' actions and democratic decision-making. Engineering as a threat to democracy? Her discussion leads one to answer: Yes indeed, especially among engineers networking in complex projects where individual responsibility is dissipated to nil.

The New Engineer is written primarily for engineering students. This possibly forces Beder to tiptoe around her subject. She is careful not to antagonise or denigrate engineers but rather to encourage them by pointing at the initiatives that have been taken world-wide at various levels to improve engineering practice. Her book, despite its off-putting examples of engineering malpractice in the past, breathes an optimism for engineering as a social activity and "New" is used in the same hopeful way as it is in the journal *New Scientist*. The appendices present a number of real cases supplemented with questions for reflection and discussion and the bibliography lists around 500 publications.

What can we learn from (engineering) history? First, that we seldom if ever learn (engineering) history. History of Technology is in many schools of engineering despised as an 'airy-fairy' subject, not worthy of inclusion in the curriculum. And 'Disasters Analysis' is also a much neglected subject. The lack of 'closure' in these subjects presents a problem for Beder's plea for more non-technical subjects in engineering courses. From a series of interviews I made at the Royal Institute of Technology, Stockholm, I suggest that many engineering students are reluctant to tackle ambiguity. Environmental problems are complex and tend to be ignored rather than solved. How, then, ought one to approach conservative people with power who do not want their students to study the social implications of engineering and, even if they are interested, are not willing to give room for it in an already overloaded curriculum? Those who most need to read Beder's book are the ones least likely to do so. I am afraid we will have to wait some time for the 'new engineers' to emerge.

Reading Beder's book raises a number of fundamental issues. Engineering is a constituent part of western civilisation, and we need to dig deeper in order to understand where this civilisation is taking us. Perhaps Beder needed to tackle more directly the philosophy, psychology

and sociology of engineering, fields of study that are growing. The recent trend towards Problem-Based Learning (PBL) seems to be an opening for a more holistic approach to engineering. Here out-dated models from cognitive psychology have been replaced by a stress on fostering 'problem-sensitivity' rather than 'problem-solving' skills, and generic and transferable skills are lifted to the same level of importance as scientific skills. An important centre for PBL is based in the Department of Civil Engineering at Monash University, Australia. Sharon Beder is also Australian. This coincidence is not accidental.

Swedish Embassy,
Dar Es Salaam,Tanzania.

By Jean Armstrong

I READ this book with a mixture of fascination and frustration. Fascination because it brought together ideas and examples concerning the engineering profession and engineering education I had never encountered before, which resonated with my own personal experience. Frustration because it uses language which most engineering students would find extremely difficult. This undermines the book's stated aim which is to "provide a resource to help engineering students understand the social role and responsibilities of the new engineer as well as the social dimensions and context of engineering work" (p. xv).

The first of the book's three main parts describes the characteristics of the traditional engineer and the nature of engineering. The second is a detailed case study of the history of sewage treatment in Sydney. The third deals with issues facing engineers now and in the future, including ethical, political and environmental concerns.

The first part was for this reader the most interesting. The accepted wisdom that mathematics and science form the basis of engineering is challenged and an historical explanation of the move of engineering towards applied science is given. Many innovative Australian educators will take comfort from the statement by Ferguson which Beder quotes: "The real 'problem' of engineering education is the implicit acceptance of the notion that high-status analytical courses are superior to those that encourage the student to develop an intuitive 'feel' for the incalculable complexity of engineering practice in the real world" (p. 7).

However, the statement that "Most engineering educators would agree that high-level mathematics and calculus have little relevance to most engineering work" is not supported by the many discussions which this

reader has had with a wide cross-section of Australian engineering educators. For most, their understanding of engineering topics is so closely associated with the mathematical way in which they themselves learned that they are not able to accept that any other approach is possible. Interestingly, the two sources that Beder quotes in support of this statement relate to US and UK studies. Implicit in much of this discussion is the assumption that results from the UK and US also apply to Australia.

Many engineers believe that they deserve, but do not have, a status equal to doctors and lawyers. There is constant discussion of this 'lack of status' within the profession. This book, however, introduces other insights not normally raised, including the significant fact that most engineers are employed by large organisations whilst many other professionals are self-employed or work for small organisations. The size of the place of employment may have serious implications for the career structure, responsibilities and freedom of action of engineers.

While much of the material in this first part would be of interest to engineering students, the format and style are inappropriate for undergraduate use. Most undergraduates would find it difficult. Beder herself notes that engineers have a low tolerance to ambiguity and lack good verbal and writing abilities yet the book does not work hard enough to accommodate these shortcomings. While the nature of the topic makes ambiguity unavoidable, the writing could have been more inviting to the average engineering student. The presentation is in the form of a learned thesis. Findings of individual authors are summarised but little attempt is made to fit these into any overall structure. Even simple editorial changes, such as having summaries at the beginning of each chapter and section to outline the overall structure of the following material, would have helped. Some of the more complex grammatical structures and obscure words could have been avoided or explained.

Another criticism is that many references seem rather old. For example, the main references on women in engineering are dated 1983. Since then there has been a vast amount of work in Australia on issues of women in engineering. For example, the annual Australasian Women in Engineering Forum, held annually since 1994 publishes *Proceedings*, as does the annual conference of the Australasian Association of Engineering Education. Many issues of the *Australasian Journal of Engineering Education* also carry relevant material. In addition, most universities in the past decade have employed 'women in engineering' coordinators, and the proportion of females studying engineering has greatly increased. Engineering itself has changed over the last two decades. Computers have become readily available (as Beder herself comments), the volume of engineering knowledge has increased and environmental and other social

issues have become more prominent. While the older references may still be relevant some more recent context for them is necessary.

The second part is a long and detailed study of the development of the Sydney sewerage system and the environmental, political and ethical issues involved. While this topic would probably be of interest to civil and environmental engineers, engineering students from other disciplines will find it irrelevant. This reader was unconvinced by some of the conclusions. In a number of places Beder suggests, without any supporting references, concerted action by engineers. For example, "Whilst the government could achieve sanitary reform aims, engineers saw the opportunity to establish themselves as experts in a new field of sanitary engineering and to increase their role in city management" (p. 108). It would certainly be unusual for modern day engineers to achieve such conspiratorial success. The argument of Tarr and McMichael that Beder quotes seems more convincing: "the reliance on incrementalism and retrofit has obscured the long-term costs of using waterways for waste disposal and prevented full consideration of radical alternatives to the water-carriage system that the magnitude of the waste problem deserves" (p. 112).

The third part deals with the social role and responsibilities of the 'new engineer'. Topics include environmental issues, the role of experts, ethical issues and the potential legal liabilities of engineers. There are many interesting examples, but again, almost all are taken from environmental, chemical and civil engineering. The large and increasing proportion of engineers in disciplines such as electronic, software and telecommunications engineering will not find these directly relevant. The ethical and social issues facing these engineers are not touched. These are issues such as the privacy implications of much new communications and computer technology. What are the ethical implications of working on new microcomputer technology which has such diverse applications as aids for the disabled, children's toys and weapons guidance systems? What are the ethics of working on 'defence' projects?

In conclusion, this book is an interesting source of information about a number of aspects of the engineering profession in the UK, Australia and the US. It brings together a number of case studies and information about overseas and Australian research that most engineers and engineering-educators in Australia will not have encountered. While I have no hesitation recommending it to other engineering academics as an interesting and thought-provoking read, I would only recommend it to the most literate of undergraduates.

Department of Electronic Engineering,
Latrobe University, Victoria, Australia.

By Helen Armstrong

THE call for sustainable places has generated a new type of engineering practice called 'soft engineering' which has broadened the engineering team to include landscape architects, ecologists and even artists. Landscape architects, in particular, have become heavily involved in constructed wetlands as an alternative to concrete surface stormwater channels. Because many stormwater channels run through public open space, it has been possible to create new wetlands within parkland as an alternative to the conventional engineered trunk drainage networks which are designed to remove urban runoff as quickly as possible. These new wetlands are called multiple use drainage systems and have become the focus of attention by politicians and community groups in the 1990s.

Restoring the Waters, an innovative project in Fairfield, South Western Sydney, has been a particularly successful example of collaboration between engineers, landscape architects, ecologists, artists and community groups. The project has involved artists and landscape architects undertaking community awareness art projects as a precursor to the removal of the concrete stormwater channel in the local parkland. The artists worked with many different community groups on projects about water management. They also undertook a temporary art installation in the form of a planting, two metres wide and the length of the existing concrete channel, of rye which followed a 'memory line' of where the creek originally flowed. Subsequent work will involve artists working with engineers to develop designs for the gross pollutant traps and landscape architects working with hydraulic engineers to design the wetlands and retention basins. Ecologists will work with the teams to determine the flora and fauna most suitable for the project.

This urban water management project, funded by Nature Conservation Foundation and the Australia Council, was launched by the very engineer who had designed the concrete surface water channels about to be removed. He commented that when he designed the channels in the 1970s he was extremely proud of them, but he now realises that there are other issues apart from the rapid removal of urban water. He is a 'new engineer'.

Engineers who develop multiple use drainage systems need particular qualities. They need a broader social awareness of the implications of their designs, they need well-developed skills to communicate with professionals with other expertise and the lay-public, and they need to be comfortable and productive in collaborative teams. Sharon Beder's book

points out that traditionally engineers have been trained to relinquish such qualities in order to be highly focused, objective technocrats.

Some engineers are now required to work with artists on such complex problems as remediation of toxic sites. In earlier eras, these were the exclusive realm of science and technology experts. After countless millions of dollars spent on technological fixes, many toxic sites remain as toxic as before remediation processes started. Such failures inevitably contribute to a loss of confidence by the community and the profession. The Pig's Eye landfill site in St Paul, Minnesota has been the location of an interesting collaboration between artist Mel Chin and senior research scientist Rufus L. Chaney, at the US Department of Agriculture at Beltsville, Maryland. The art work, called Revival Fields, was a planting design of hyper-accumulator crop plants which included performance and other community awareness activities. How does a traditional engineer cope with performance and dance as part of his or her professional practice? In Brisbane, in a new project initiated by Queensland University of Technology and Brisbane City Council, a landscape architect is working on a toxic site developing planting designs for bioremediation that are also forms of environmental art to inform the community of the remediation process. Can our traditional ways of training engineers embrace this sort of soft engineering?

Beder develops a cogent and thorough explanation of why engineers have become so focused and as a result, so unable to be the leaders in the changes that are happening around them. She shows how engineering as a profession has carried high status, closely aligned with scientific discipline and objectivity, while at the same time embodying notions of the creative designer. She explains how engineering design has changed from pre-industrial to modern—a process that has many parallels in architectural design. Prior to the industrial revolution, designs were based on repeating tried and tested methods, where practice was a craft. Beder points out that modern design methods use scale drawing as the medium. As a result, experiment and change have become separated from production. The engineer is no longer the craftsperson making changes.

The engineer became further removed from the product through the practice of scale drawings. Materials and components can be specified in advance, resulting in a division of labour between design and production. Engineers shifted from manufacture to making drawings. Add to this computer generated design and the engineer becomes even further removed from the real context of the product while being lulled by the computer into a false sense of accuracy. Beder argues convincingly that we now need "to re-integrate environmental considerations into the design process which will therefore be a move back to the user context".

As noted by the other symposiasts, Beder structures the book into three parts. The first locates the engineer in past and present contexts and considers the role technical factors play in engineering decision making. She points out that although engineers pride themselves on their scientific objectivity, their decisions are constantly framed in a social, political and economic context. This is illustrated with a case study about choosing between the development of gas or electric technologies for refrigeration. The case study indicates that decisions were driven by agendas which were best for the producer but not in the best interests of the consumer.

In describing the culture of engineering, Beder shows that engineering is characterised by conservative inventions, namely the improvement of existing systems. Radical inventions are not developed by engineers but by individuals outside the profession. The technological paradigm has a linear trajectory resulting in more and more refinement of the original idea.

Beder brings out the political issues involved in engineering practice by contrasting nuclear with solar power. Nuclear power can only occur where centralised, authoritarian political power structures in association with experts control the system in order to prevent unacceptable risks. Solar power, by contrast, is more compatible with democratic egalitarian societies. Solar power can be established in a small scale decentralised way that enables local communities to control their own energy production. The political and economic implications of this have a direct relationship with funding for research and development and hence engineering practice.

The second part takes a case study, managing urban sewage, to show how engineering practice is driven by politics and economics and how engineers have colluded with such values. The case study is particularly interesting for Sydneysiders who enjoy swimming and the beach. Beder undertakes an exhaustive study of the history of the management of sewage in Sydney from first settlement up to the present. Although her subheadings are catchy and informal, the diligence of a PhD thesis is evident in the large amount of historical detail provided, making this section somewhat laboured. Some tough editing could have maintained her earlier racy and highly readable writing style, despite the somewhat off-putting theme of this section.

The sewage case study is ideal for illustrating the social dimension of engineering decisions. It is generally assumed that major decisions about the kinds of sewage removal technologies, treatment processes and disposal methods are based on purely technical and economic questions. Beder criticises the linear technological trajectory based on cost-effectiveness and rationality and shows that an interactive model of

technological development is more appropriate. This is because such a model acknowledges the interweaving of social, political, economic and technical factors in the decision-making process from first conception of the project through to its implementation and operation. She argues that such a model would be the first step in developing 'new engineers' who will take their social responsibility and ethical duties seriously.

The case study on sewage management reveals some alarming facts about the way different decisions were made, including the total dismissal of community knowledge which resulted in health hazards that need never have occurred. Beder shows that a subtle shift in the engineering paradigm could bring about significant change in engineering practice. She suggests that if engineers could relinquish their pride in achieving minimum designs that still comply with the legislation and instead develop pride in producing environmentally beneficial solutions that go beyond the legal standards of 'good enough', then the new engineer would emerge. For Beder, "engineering knowledge is not about truth, nor does it describe reality, past, present or future. It is about a special blend of know-how, ideology and representation aimed at achieving ends".

Part Three looks at social responsibility and the new engineer. This section draws together all the earlier arguments and evidence to show the realities of engineering culture today. Engineers today must work with loss of community confidence in technology, litigation risks, an uncertain role of the expert and an increasing importance of professional ethics. The Institute of Engineers supports the paradigm shift in engineering practice including respect for Environmentally Sustainable Design, community participation in decision making and a code of ethics that would respect the voices of dissent sounded by certain engineers who were ignored at Chernobyl and Bhopal, and on the Challenger Space shuttle programme.

Beder suggests we can achieve this new engineer through the training students receive at universities. Perhaps we can learn from Margaret Wertheim's *Pythagoras' Trousers*, which highlights the role gender plays in thinking differently. Wertheim points out that science and religion have been the traditional domain of men, while magic and witchcraft were associated with women—except for the French salons of the eighteenth century where women acted as powerbrokers for ambitious and talented young men, many of whom were scientists. Not all French scholars agreed with this situation. Rousseau argued that, in the presence of women, men were forced to "clothe their reason in gallantry" which lowered the level of intellectual discourse. However Diderot and others thought the salons had a beneficial effect on the male intellect, forcing men to clarify and refine their ideas.

Beder's book is a fine example of a level of intellectual discourse which would satisfy even Rousseau. If engineers could see their way to accept more women into their profession—and many of the landscape architects and artists working on soft engineering projects are women—they might clothe their reason with humility and clarify and refine their ideas. A more gender-inclusive engineering profession would go a long way towards fostering 'new engineers'.

Department of Landscape Architecture,
Queensland University of Technology,
Brisbane, Australia.

Author's Response

By Sharon Beder

ENGINEERS worldwide are unhappy with their present status in the community. In Australia the Institution of Engineers (IEAust) has tried a million dollar public relations campaign to raise the status of engineers, but with limited success. Over the past two decades various official inquiries have been made into the decline in status of the British engineer since the glory days of the early nineteenth century when engineers were the heroes of poetry and novels. At the same time, disasters such as the one described by Sören Törnqvist bring engineers into further public disrespect. Engineers are increasingly identified with environmentally damaging projects and developments whilst few hear of the rare attempts at environmental integration such as those Helen Armstrong describes.

Surveys show that employers increasingly feel that engineers lack social understanding and interpersonal and other skills not traditionally part of the engineering curriculum. And there has been a decline in the number of engineers filling management roles in public works organisations in both the US and Australia. They are being replaced with people who have more formal management training.

For all these reasons reviews of engineering education in several countries, including Australia, the US, the UK and Canada, have been calling for a broadening of engineering education to cover the social, ethical, professional and management material. So whilst there is some

remnant resistance, as Törnqvist rightly points out, to the inclusion of this material into engineering courses, the tide is turning. The professional engineering societies, their members and even employers are demanding this change.

Whilst a few students may be reluctant to engage in the ambiguity of social and ethical issues and to exercise their critical faculties in areas foreign to traditional engineering subject matter, most accept and enjoy the challenge. *The New Engineer* is already in use as a text at the University of Wollongong at undergraduate level and engineering students, even at first year level, have no problem with its language or concepts. Perhaps Jean Armstrong underestimates her students. She also underestimates the ability of students to extrapolate examples from various branches of engineering to their own future work situations. However her contention that the third part lacks examples for electronic, software and telecommunications engineers indicates that she may have missed the BART case study, which covers three engineers—an electrical engineer, a systems engineer and an engineer working as a programmer/analyst—who blew the whistle on their employers.

A couple of years ago the UK magazine *Professional Engineering* published an article entitled "Is there a bit of the Rain Man in every engineer?" which compared the supposedly typical personality profile of engineers with children who have autism. Autistic children don't develop normal social relationships and they tend to wander off by themselves and play with mechanical things. The article said that engineers and autistic children shared various characteristics including strong visualisation skills, strong affinity with physical objects and being "less interested in social activities and communication".

It would be a shame if such stereotypes of engineers continued. Whilst public relations campaigns such as IEAust's have had limited success, the real change will come through changing the culture of engineering and this can only happen if engineering education changes. This view was endorsed by the 1996 Review of Engineering Education in Australia which was entitled Changing the Culture. *The New Engineer* is my contribution to this challenge.

Department of Science and Technology Studies,
University of Wollongong,
Wollongong, New South Wales, Australia.