Engineering and social justice

For many years I have been worried about what I did for a living. I was worried that we seemed to be focusing on anything that made the world faster, more efficient and that gave us as the researchers and designers more power, status and money. That we provided toys for those that could pay instead of food and water for those that couldn't. That we didn't care what became of the environment. I understood that the values that were embedded in engineering reflected those of the society around me – we were expected to respect power, status and money instead of those timeless values of goodness, truth and beauty (this last one perhaps but not in the sense that I meant it). At first I thought it was because I was female but I soon discovered that it wasn't I that had the problem – it was the profession. Many others felt the same way, men and women, but felt powerless to do anything about it. I started to work with engineering education at that time, believing that through education we could help to raise awareness about the possible futures that engineering could bring. I had a naïve sort of belief that if students were encouraged to think for themselves rather than reproduce what was given to them that they might start to rethink what we were doing to our world. I began to do research in areas that matched my values, questioning everything, incentives, funding schemes, research programmes. The more you truly know, the more you cannot forget.

This document lays out a picture, painted by many scholars in different disciplines, a picture that sees into the future. It is an attempt to begin the process of relocating engineering with the people that it is intended to serve. All people. Most of us entered the profession because we wanted to make the world a better place but those whose conscience could not allow them to stay have already left. Many students do not enter this career path if they have a social conscience. To undo what has been done, and to sew the seeds of a new engineering will take time and the efforts of many people from all areas of society. When we read the newspapers every day about unnecessary deaths caused by wars, earthquakes that we are not warned about, poverty, disease and hunger, we think that the job is too large for us to do anything. We hold up our hands in despair. We stop reading the newspaper. This time, we invite you to join in a conversation – a global, constructive, peaceful, loving dialogue between friends – to share ideas, question motivations, create strategies and new research, new teachings and new beginnings. This is not a manifesto telling people how to think. It is not another movement or club that can make us, as the organisers feel important. It is a way of introducing the subject and opening up the conversation.

Our ultimate aim is to develop the theoretical and practical underpinnings of an engineering education which promotes a socially just engineering practice. We understand socially just engineering practice to be that which will promote economic and environmental sustainability for all, whilst specifically addressing issues of poverty and inequality. Engineering discourse generally appears to display a lack of reflexivity with regard to its theoretical and political commitments. Williams (2003) suggests that the engineering profession suffers from 'a loss in identity'. We hope to increase awareness of

how engineering is implicated in broadly social, economic and political structures and consider the ramifications of this within engineering education.

Heather Menzies (1996) in 'Whose brave new world' shares a concern of ours that we are through our educational programmes 'training for compliance', she says that 'once people are totally closed off inside a fully programmed work environment, once they are wired in through computer-monitoring and performance measurement, they will have little choice but to comply: to willingly participate in fine-tuning the new work model.' But the new economy, she stresses, 'promises to be less and less our economy – sustaining us all with jobs, livelihoods, leisure and opportunities to participate, and simply a chance to live at peace with ourselves, our families, friends and neighbours – because it is not grounded in the social environment of communities, let alone the natural environment, with a finite sense of time and space. It is grounded in an entirely simulated environment: that of corporate systems economy driven by global stock and bond markets and their constant appetite for profit margins..massive restructuring is closely linked to some dramatic new developments in the so-called labour market: protracted high levels of unemployment even in times of economic growth and record-breaking profits: rising levels of underemployment: and a polarization of the workforce into the working rich and the working poor.' (p10-19).

This new world finds its way into our consciousness in subtle ways. I have recently changed country, moving from the UK to Canada. It is when we are at the boundary, that we can see things clearly. When we are immersed into the thought collectives (Fleck 1981) of the discipline or the culture, we find it more difficult to keep our eyes open, to look around us and gaze in wonder, like children. We become acclimatised and accustomed to the rituals, still aware of them but no longer surprised. I read in the newspaper recently that a journalist in London had been surprised and delighted that Coe et al had won the Olympic Games bid, and the very next day was not atall surprised to hear that London was closed due to bomb attacks. Menzies warns us about the prevailing language which pervades the way we think and subsequently act. 'I walk the walk, talk the talk.. I could debate 'redundancies, downsizing and deskilling…' and this she suggests reminds us of Orwell's 'Newspeak'. It had a double purpose. Firstly it was to bypass the need for personally grounded meanings through which people could check the authenticity or relevance of words e.g. 'double-good' and 'double-plus good' instead of 'beautiful' and 'just'. Secondly it was to eradicate traditional and personal meanings - so that you couldn't and didn't think for yourself..'.New investment and everything that contributes to it are good, double-good or double-plus good; and whatever detracts from this ..nursing the sick, caring for the young and old - are negative burdens, coded as bad or double-bad to be dealt with through spending cuts and privatisation..' Menzies is obviously influenced by Ursula Franklin who discusses in her book 'The Real world of technology' (1990) the need for attention to language: whenever someone talks to you about the benefits and costs of a particular project, don't ask ' what benefits?' ask 'whose benefits and whose costs?'

At this point those fearing the suggestion of a conspiracy theory might reflect that there is no overt conspiracy to corrupt language – Menzies suggests that 'it is built into communication mechanisms.. eventually full submission occurs' (Menzies 1996, p10-19). She claims that none of this is inevitable. 'The changes so far have been the result of choices made in the design and implementation of technology, and in organizational restructuring and policies around it – choices which people as workers, consumers and citizens have had no real control and little say. ..to challenge these changes ..we must first break the immobilizing gaze of the adjustment regime..' She tells us 'we must articulate a new critical discourse on technology'. Menzies is not blaming technology for what we see around us. But she is worried about how we use what we create – the multimedia technologies or information highway, that she is concerned about should be 'designed and structured to be truly democratic, inclusive and participatory' (p12). Rosalind Williams (2005) points out that 'Capitalism in many ways is detaching itself from the industrial base – production is not where the money is'. Hardt and Negri (2000) discuss in details this 'Immaterial labour' – the new informational economy.

This document serves to explore the questions raised in the above account. How far should we be worried that engineering can and is contributing to a corporate system which controls and homogenizes whilst supporting the increasing gap between the rich and the poor? If we agree that we are worried, can we do anything about it in our education of future engineers, or should we leave this to the politicians, the economists and the sociologists?

Ursula Franklin mentioned above, has been a long time Canadian activist in the area of engineering and society and poses some important questions which help us with some frameworks to consider. Some key arguments in her book are as follows:

Technology is defined as 'practice' or 'ways of doing something' which links to culture as culture is a 'set of socially accepted practices and values'. 'A way of doing something' is 'holistic' when the doer is in control of the work process. The way of doing something can be 'prescriptive' when the work is controlled and divided into specified steps each carried out by an individual. Bureaucracy is the 'acculturation into a culture of compliance built on the willing adherence to prescription and the acceptance as normal of external control and management'(p114-116). The prescriptive nature of technology and social consequences of the division of labour is important to the appreciation of the speed and strength of the spread of technology. There is a separation of expertise from direct experience and a need to evaluate experiences of those at the receiving end of the technology. For example, she tells us 'Communications' technologies have become 'non-communication technologies' - the absence of reciprocity is developed. We cannot feed back to the television when we don't agree – as we could in a live talk or debate. Since the Industrial revolution, publicly financed infrastructures were created supporting new technologies. This is accompanied by governments neglecting many people as 'indivisible benefits'. These infrastructures lead largely to divisible benefits, venues of private and corporate profit rather than indivisible benefits such as clean air and uncontaminated water are less and less safe guarded. The environment is therefore treated as two separate components - a built and constructed 'environment' a product of

technology and ‘nature’ which is not. Nature is not an infrastructure to be adjusted. She states ‘I would wish that the government of Canada would treat nature with the same respect with which all governments of Canada have always treated the United States as a great power and force to fear’(p117-119).

Franklin goes on to explain that values of technology have so permeated the public mind that all too frequently what is efficient is seen as the right thing to do. She would like to see public discourse break away from this mindset to one which focuses on justice, fairness and equality in the global sense. People need to be reintegrated into the technological decision making process and develop redemptive technologies. There needs to be an analysis of unacceptable practices of existing technologies e.g. redesigning industrial processes to reduce waste, an analysis of things that do work and a definition of as yet unmet needs’ (p126-127)

Her work has been continued by Bill Vanderburg (1985, 2000) who has also clearly been influenced by his teacher Ellul (1967) where he studies the interconnections with other things within a wider whole. His main contribution is the notion of ‘preventative engineering’ where he looks at cost – balance e.g. how expensive it is to have health care as one of the major expenses of a company – if we look after the worker we will pay out less. He claims that it is possible for companies to make a profit by taking care of the environment and social impact – and that in the long run this will be a financial gain for them. If companies plan for impact then they will ‘prevent’ the costs of health problems, liability and environmental implications. He is socally minded and ensures that we consider all of society in this cost balance approach. One things is clear, Vanderburg is not addressing the problem of the profit motive but embraces it and tries to create a system which will work within the current political and economic framework.

David Noble (1984) in contrast asks us of technological progress ‘for what or for whom?’ and poses that technological developments are often made in the name of patriotism, and competitiveness with the twin aims of control and domination. We see a shift of control to management. We are told that efficiency in automation is developed to reduce cost and yet for the military uniformity and performance are targeted, regardless of cost. Innovation is thus shrouded by the ideology of efficiency by managers who simply seek authority at the expense of workers.

Does it seem possible that we can simply ignore the huge contribution that engineering has made to capitalism and now assume that we can work within its framing to reverse the negative effects? Certainly we cannot equate engineering to capitalism. There has always been a social strand to engineering practice, civil engineering or engineering for the people, geological engineering and more recently environmental engineering can be seen as largely developing the systems and infrastructures needed by communities. These industries have not been unaffected by capitalism, far from it, but they were not driven by it in quite the same way as the manufacturing industries, aeronautical, mechanical and chemical process engineering, electrical engineering and materials engineering. However, today it is rather difficult to separate engineering as a profession from the large corporations that employ most of our graduates. And large engineering corporations are

often named as the cause of extreme poverty. Recent discussion in the press (George Monbiot, Guardian Weekly, July 15th – 21st) about the G8 conference claimed that 'the history of corporate involvement in Africa is one of forced labour, tax evasion, and collusion with dictators. Nothing in either the Investment Climate Facility or the Growth and Opportunity Act imposes mandatory constraints on corporations. While their power and profits in Africa will be enhanced with the help of our foreign-aid budgets, they will be bound only by voluntary commitments: of the kind that have been in place since 1973 and have proved useless'.. 'without a critique of power, our campaign, so marvelously and so disastrously inclusive, will merely enhance this effort. Debt, unfair terms of trade and poverty are not causes of Africa's problems but symptoms. The cause is power: the ability of the G8 nations and their corporations to run other people's lives..'

Furthermore, when the Oil industry is behind the US Govt's determination to cover up evidence about climate change (New York Times and Guardian Weekly July 2005) , strikeout results and 'investigate' scientists who find positive evidence we can only assume that profit is not only more important than people today, it is more important than our children as well.

Whilst engineering becomes increasingly equated with corporations whose profit motive limits their ability to act on behalf of the broader social issues we cannot expect to rediscover an engineering practice whose aims are noble and just. Many engineers and academics entered the profession to do good for the world, contrary to popular misconception that we all became engineers to make lots of money. Had we wanted to do that we would have gone into finance – similar skill set required. This is not to say that there are not many engineers out there for whom this is true. These professionals usually end up running the businesses anyway. However, what is of more concern is that the more we become disassociated with social good, instead of personal profit, we will attract an increasingly selfish student whose main aim is to get power, money and status as quickly as possible whatever the cost to family, and the broader society. And we wonder why women continue not to be attracted to the profession – it has been proven that female engineering students are more interested in the social relevance of engineering than their male colleagues.

It is quite clear that engineering 'has been central to the economic growth characterising the rise of industrial capitalism' and yet engineers 'have generally ignored questions of the distribution of the resulting benefits and often even questions of the social character of production processes' (Johnson, 2000, p534). Winner (1986) frames well the question we might ask here, 'If we examine social patterns that characterize the environments of technical systems, we find certain devices and systems almost invariably linked to specific ways of organizing power and authority. The important question is: Does this state of affairs derive from an unavoidable social response to intractable properties in the things themselves, or is it instead a pattern imposed independently by a governing body, ruling class or some social or cultural institution to further its own purposes?' As Johnson quotes from Goldman (1990, p133) '.. the constraints they (engineers) must satisfy come from outside engineering: from managerial interpretations of the marketplace, of institutional needs, of political objectives, or of corporate agendas'.

It is not as though many scholars and practioners have not realized the huge contribution that engineering makes to the way that we live and therefore to issues of social justice and equity. Brawley (2003) suggests that technology plays an important role in promoting changes in economic activities by altering the costs of various choices. He suggests that technology is a key factor in competitiveness between states and that technical education is what makes the difference.

We can see things most clearly when we make comparisons between countries with very different economic and political structures. Graham (1998) describes the differences in the ways in which megaprojects are conducted in the US compared with how they were conducted in Soviet Union and China. The standard argument is that the US projects are increasingly 'participatory' with the public, however he makes it clear that this can lead to a new type of engineer 'one who is as skilled at manipulating the public with public relations as with the old type used to be at manipulating it by claiming superior technical knowledge…in the old days engineers talked of the 'scientific management of recalcitrant workers who tended to loiter on the shop floor'. Today engineers speak of 'managing the public which tends to get obstreperous with large construction projects' (p122). This new type of engineer has learned the language of public hearings, of the courts and of community relations'.

A case worth mentioning at this point is provided by Capra (2002) who discusses the Biotech industry in relation to some of our broader concerns. 'The Biotech ads portray a brave new world in which nature will be brought under control. Its plants will be genetically engineered commodities, tailored to customer's needs…. Agriculture will no longer be dependant on chemicals and hence will no longer damage the environment. Food will be better and safer than ever before, and world hunger will disappear. .. many of us remember vividly that very similar language was used by the same agrochemical corporations when they promoted a new era of chemical farming, hailed as the 'Green Revolution'. … It is well known today that the Green Revolution has helped neither farmers nor the land nor the consumers. The massive use of fertilizers and pesticides changed the whole fabric of agriculture and farming, as the agrochemical industry persuaded farmers that they could make money by planting larger fields with a single highly profitable crop and by controlling weeds and pests with chemicals. ..With the new chemicals, farming became mechanized and energy intensive favouring large corporate farmers with sufficient capital .. all over the world, large numbers of people have left the rural areas and joined the masses of urban unemployed as victims of the Green Revolution…The long term effects of excessive chemical farming have been disastrous for the health of the soil and for human health for our social relations and for the entire natural environment..The simple truth is that most innovations in food biotechnology have been profit – driven rather than need – driven. For example, soybeans were engineered by Monsanto to be resistant specifically to the company's herbicide Roundup so as to increase the sales of that product. Monsanto also produced cotton seeds containing an insecticide gene in order to boost seed sales… Numerous side effects have been observed in genetically modified plant and animal species… Monsanto is now facing an increasing number of lawsuits from farmers who had to cope with these

unexpected side-effects…canola seeds had to be pulled off the Canadian market because of contamination with a hazardous gene'…(Furthermore) recent experimental trials have shown that GM seeds do not increase crop yields significantly. Moreover there are strong indications that the widespread use of GM crops will not only fail to solve the problem of hunger, but on the contrary may perpetuate and even aggravate it. If transgenic genes continue to be developed and promoted by private corporations, poor farmers will not be able to afford them, and if the biotech industry continues to protect its products by patents that prevent farmers from storing and trading seeds, the poor will become further dependant and marginalized..according to a recent report… 'GM crops are ..creating classic preconditions for hunger and famine'. (p158-206)

As Polyani (2001) states 'the true criticism of market society is not that it was based on economics…but that its economy was based on self interest' and we see the results as there is now 'Fullness of freedom for those whose income, leisure and security need no enhancing and a mere pittance of liberty for the people who may in vain attempt to make use of their democratic rights to gain shelter from the power of the owners of property'

There has been in the past a focus on the balance between Government and market. The US especially, has been very concerned about what they call 'freedom' from Govt restrictions. However it is clear that today global networks have the power and Rosalind Williams states that 'market is not capable of sustaining itself over long periods of time because you need the structures of regulation….' (2005). It is not only the outsiders who feel concern for our current world situation. Stiglitz who worked inside the US Govt for many years (2003) tells us that he has observed first hand the 'level of pain in developing countries in the process of globalization' and worries about issues of intellectual property rights and bio 'piracy'. There is much to be concerned about, not only from the appropriation of local indigenous knowledge (Smilie, 1991). 'Advances in technology affecting production and dissemination of cultural products are at the root of cultural globalization. Homogenisation is happening – a virtual annihilation of space through time (Giddens, 1986).

Capra has more to say on this topic. 'During the last decade of the twentieth century, a recognition grew among entrepreneurs, politicians, social scientists, community leaders, grass roots activists, artists, cultural historians and ordinary women and men from all walks of life that a new world was emerging – a world shaped by new technologies, new social structures, a new economy and a new culture.. 'Globalisation'. With the creation of the World Trade Organisation (WTO) in the mid-1990s, economic globalization, characterized by 'free trade' was hailed by corporate leaders and politicians as a new order that would benefit all nations, providing worldwide expansion whose wealth would trickle down to all. However it soon became apparent to increasing numbers of environmentalists and grassroots activists that the new economic rules established by the WTO were manifestly unsustainable and were producing a multitude of interconnected fatal consequences and extensive deterioration of the environment, the spread of new diseases and increasing poverty and alienation….in addition to its economic instability, the current form of global capitalism is ecologically and socially unsustainable and hence not viable in the long run. ' (p 130 – 157) Capra (2002)

More detail is available in 'Empire' (Hardt and Negri, 2000) which is cast off by the New York Review of Books (Tony Judt) as 'dreadful' mostly because ' in place of the boring old class struggle we have the voracious imperial nexus now facing a challenger of its own creation, the de-centered multitudinous commonality: Alien versus predator.' However, I will use the text here as I think it contains a rather good description of the emerging global network which is displacing the nation state as the arbiter of capital. And to dismiss the book in its entirety because one of the authors is a political prisoner and because of its strange postmodern language as much as because it is the 'Das Capital' of the 20th century is to miss out on many of the eloquent arguments it contains.

The authors discuss that 'Marx analyses capital's constant need for expansion first by focusing on the process of realisation and thus on the unequal quantitative relationship between the worker as producer and the worker as consumer of commodities. The problem of realization is one of the factors that drives capital beyond its boundaries and poses the tendency toward the world market… capital expands not only to meet the needs of realization and find new markets but also to satisfy the requirements of the subsequent moment in the cycle of accumulation, that is, the process of capitalization.. The capitalization of realized surplus value requires that for the subsequent cycle of production the capitalist will have to secure for purchase additional supplies of constant capital (raw materials, machinery etc) and variable capital (labour power) and inturn this will require ..greater expansion. . The search for additional constant capital (in particular, more and newer materials) drives capital toward a kind of imperialism characterized by pillage and theft. Capital, Rosa Luxembourg asserts 'ransacks the whole world, it procures its means of production from all corners of the earth, seizing them if necessary by force from all levels of civilization and from all forms of society…' (p222-225)

Capital they tell us ' must therefore not only have open exchange with noncapitalist societies or only appropriate their wealth; it must also actually transform them into capitalist societies themselves. Rudolf Hilferding calls this the 'export of capital' (p226). ..capitalisation poses a barrier to realization and vice versa; or better, internalization contradicts the reliance on the outside. Capitals thirst must be quenched with new blood, and it must continually seek new frontiers.' (p227)

Many of our engineering colleagues will tell us that there are no alternatives so we may as well work within the system rather than try to fight against the inevitable. MacEwan (1999) claims, however, that there are economic alternatives which are practical and which could be implemented within the existing socio-economic framework and bring about change in social organization and power. He believes that it is possible, without revolution to challenge existing relations of power and authority and move towards a democratic structure by structural reorganization. A model worth considering looks at the notion of 'freedom' as the goal for all individuals within a society as demonstrated by Amartya Sen (Nobel Prize winning economist) in 'Development as Freedom' (Sen, 2000) and I attempt here to summarise the key features.

Sen introduces us to the notion of 'capabilities' of persons to lead the kind of lives they value and have reason to value. These capabilities can be enhanced by public policy but also the direction of public policy can be influenced by the effective use of participatory capabilities by the public. Having greater freedom to do the things one has reason to value is significant in itself for the persons overall freedom and important in fostering the persons opportunity to have valuable outcomes. Not only can we use this basis to evaluate freedom in a society but it is also a determinant in social effectiveness of an individual. Greater freedom enhances the ability of people to help themselves and to influence the world. His approach differentiates itself from traditional practical ethics and economic policy analysis, such as economic concentration on income and wealth (rather than on characteristics of human lives and substantive freedoms), utilitarian focus on mental satisfaction (rather than on creative discontent and constructive dissatisfaction) and the libertarian focus on procedures for liberty (with neglect of consequences of those procedures). There are of course connections to low income but this needs to be integrated into a bigger picture. Poverty then can be seen as deprivation of basic capabilities rather than just low income. e.g. premature mortality, significant undernourishment, persistent morbidity, illiteracy,

He points out that the extent of deprivation for particular groups in very rich countries can be comparable to that in the so called third world. In the US, African Americans have a lower longevity than citizens in very poor countries such as China, Kerala or Sri Lanka. Life expectancy is not enhanced by the growth of GNP per head but it is indicated that the connection tends to work particularly *through* the success of poverty removal. His basic issue is that the impact of economic growth depends much on how the fruits of the economic growth are used. Two types of successes in rapid reduction of mortality are described:

Growth mediated – through fast economic growth – and involves the utilization of enhanced economic prosperity to expand the relevant social services.

Support led process works through a programme of skillful social support of health care, education etc. rapid reductions in mortality without much economic growth.

Sen stresses that as much as it is desired to have both longevity and economic growth, it is not necessary to wait until the country is much richer before embarking on rapid expansion of basic education and health care (these services are based on labour which is cheap). In turn education and health are productive in raising economic growth.

Having convinced ourselves that we have a problem with the current organization of engineering which contributes to the growth of power of global corporations and yet that we do see alternative economic structures to support positive change, we might return to Engineering practice and explore the current studies on the relation between engineering and society to see if this sheds any light on our concerns. Engineering practice and technological development operate as systems of thought and practice (Menzies 1989; 1996) that control the boundaries of what can be imagined and done. The objective nature of science has been challenged time and again (Kuhn, 1962, Shapin, 1995; Zuckerman, 1988) and technologies are seen to be integrated into existing systems of social relations

and social organization. As such they need be subject to the same critique and reflection that we give to the larger systems of social relations and organizations (Mumford, 1963, 1967; Muller, 1970; Noble, 1977, 1984; MacKenzie and Wajcman, 1985). Over the past few decades, the fields of STS (Science and Technology studies, or Science and Technology in Society) have evolved from a pessimistic technological determinism (Ellul, 1967) to more recent paradigms that seek to understand the social construction of technology (Bijker et al, 1989, Bijker, 1995 p83 in Sismundo,2004). Few of today's STS researchers differentiate between technology and engineering. Some good examples of studies which deal directly with engineers are given in Bijker at al looking at 'technological systems'. They consider technology to include what people know as well as what they do.

Callon in Bijker at al (1989) discusses the notion of engineers acting as sociologists in relation to what we would call 'forecasting' for the motorcar industry in France at the beginning of the 70's. He compares this with the thinking of sociologists of the time - Touraine and Bourdieu on the dynamics of consumption. Touraine emphasized the role of class conflict in making society function and in producing history. He is not a Marxist but believes instead that technology has changed the class struggle. On one side are corporations that control application of technology and on the other is the consumer who is managed by the technocrats who run the large concerns. Social movements come into play that challenge the power of technocracy. Touraine calls this class conflict 'post industrial society'. Bourdieu's society in the other hand, shows a confrontation between social agents - many different groups but which are caught in a group logic organized around a dominant cultural model – that of the upper classes – other classes orient themselves around this. Whatever field it is – these classes are in constant competition – ever more so in the field of consumption.The post industrial case depends not only on the capacity of new protest movements to influence the choices of technocrats but also on the way in which the technology behaves.

Bourdieu's approach works in the examples given by Callon regarding the development of the motorcar in France in 1973 but the author stresses that the explanation of the preferences of the consumer omits many of the elements which make up these preferences. He therefore goes to discuss the Actor network theory (also associated with Bruno Latour) as the breaking down of distinctions between human actors and natural phenomena. This approach reverses the usual relationship between participant and analyst and casts the engineers as sociologists. In trying to extend the actor network, engineers attempt to mold society. The actor network cannot be distinguished from the actors of sociology nor can it be confused with a network linking elements that are stable and predictable. An actor network is at the same time an actor whose activities are heterogeneous elements and a network that is able to redefine and transform what it is made of. It allows us to measure the distance between the heterogeneous and 'impure' sociology of engineers and the pure sociology of the sociologists. To learn about society sociologists employ tools which have been developed over years (surveys interviews etc) or to follow innovators in their projects. Engineers are forced to develop sociological theories and sociologists learn by 'peering over the engineers' shoulder'.

Sismundo (2004) tells us that as a materialist theory it explains the successes and failures of facts and artefacts; they are the effects of the successful translation of actions, forces and interests. As a relationalist theory it suggests novel results and ecological analyses. It is not without its problems but it 'stands as the most successful of S&TS's theoretical achievements so far (p74). Despite the fact that it has often been adopted to explain market choice, perhaps it can be a useful tool for an analysis of our current situation.

We are interested in what engineering provides for all people, how needs are identified and how decisions are made. This not only involves the forces at work described above but also on the interaction with the people for whom we do the engineering. In this next section we will look at current work on what is known as 'public dialogue'. A recent report from the British Association of Science in the UK 'Connecting Science: A Review of Recent Literature on Science and Society' (Whitmarsh et al, 2005) summarises recent work in the area of public dialogue with science. In 1985 the Royal Society produced a report entitle 'Public Understanding of Science' - discussing what was seen as the transfer of scientific expertise to a largely ignorant public. In 2000 a report by the House of Lords on Science and Society maintained that we have moved beyond the deficit model of science communication to one which tries to embody 'dialogue'. The 2005 BA report attempts to summarise key areas of work and tries to be objective. It states up front that ' it is not the purpose of dialogue to intrude upon discussion amongst the science community about scientific knowledge. There is no suggestion that the progress of scientific ideas should be democratically decided' even though they state that one of the key aims of dialogue is 'increasing democracy by promoting open and transparent decision making'. So what is dialogue really about? Sir Aaron Klug, president of the UK Royal Society tells us that we need 'input from non experts to make us sure that we are aware of the boundaries of our licence'. There is of course a major belief that the public will stop scientific development due to uncertainty and inconsistency and much of the concern is less about empowering than it is about making sure that the public don't cause problems. It is stated for example that 'risk and ethics are often conflated; it is not always clear whether objections are on moral grounds or on grounds of possible consequences or both..' (p10). It is assumed that we live in a 'need to know' world and therefore it is necessary to understand better what governs this principle in different contexts. Issues relating to personal values versus in judging scientific developments are also considered. Questions are posed about 'who' is the expert, how relevant this is and how credible they are. Furthermore questions of scientific 'truth' which are still sent to school children is considered a barrier to dialogue. However, as stated earlier it is clear than non-scientists are not meant to influence the actual generation of scientific knowledge. There is still an absolutist attitude in this – the inevitability of scientific discovery. Many science communicators do not ever talk to scientists. I was told at a science TV producers meeting that no scientists ever go to the conferences and meet the media staff. Other science communicators who work with poster campaigns for outreach tell me 'we don't need to talk to the scientists'. Why not? As the play Copenhagen (Michael Frayn, 1998) discusses about the atomic bomb– who is responsible and is discovery inevitable?

The report states that the public think scientists will provide facts but distrust them to communicate the ethical and social implications. Scientists believe the implications should be relayed to the public but do not often engage in dialogue with them.The report questions the balance between 'Individual wants and social consequences' with regard to the Human genetics Commission or where nuclear power is a direct threat. It is considered that most of the 'public' will only act when it directly concerns them – this is called the (NIMBY) 'not in my back yard' phenomenon.

Much has been written about 'upstream dialogue' - intervening in the decision making process at an early stage, as well as concerns about how the dialogue is embedded in the cultural debate and how it influences it. Can dialogue really affect Government policy? Here we see much discussion on citizenship – 'dialogue is part of good citizenship' (p18) (see also Irwin, 1995). However they own – ' what we do not know is on what issues and for what reasons, the 'average' person would consider taking action… there is little data on the general question 'what would you march for?' Indeed.

The study does not take into account class as a variable and very little reference is made except where it is acknowledged that 'men, middle class people and broadsheet readers tend to be more knowledgeable about science' (p27). They also state that girls and young women are more willing to accept ambiguity than boys and young men' (p28). In issues relating to social justice we see very little – however it does state that 'half of 11-21 year olds agree that 'science cannot solve the basic human problems like poverty and unhappiness' (p31). It is interesting that it is not questioned whether or not science could inadvertently cause it however! They also report that 'Scientists for Global Responsibility' have pointed out that closer links between industry and Universities causes public distrust in scientists.

In fact there is good work, mostly in developing countries relating to community participation and technological development, participatory research and the implementation of technology, methods of community organizing (see pria.org) and participatory research and community empowerment. As well, there is a good deal of work done in Participatory Design (Emery, 1993; Kraft, 1884; Ackerman, 2000). There have also been processes like Open Space Technology that seek to encourage participatory research and community control over technological development (Owen, 1997). Jonathan barker (1999), for instance defines and characterizes 'activity settings' and has developed a methodology of participation. There appears to be very little evidence of participatory approaches being taken in engineering practice other than the 'managing the public' model described in the first section.

It becomes clear that not only do we have a problem (albeit not well defined), we also see the potential for solutions. Perhaps if engineering students could study more about the social, economic and political context of their profession they might apply their creativity to use what the scholars in other fields (such as economics, sociology and politics) have been discovering in order to redefine engineering practice in the future.

As with many STS workers, researchers within science education have challenged the special place of science as a creator of "truth" and insist on locating any given claims within the socio-cultural and political climate in which they appear and prosper (Hull, 1988; Ross, 1996; Ruse, 1999; Segerstrale, 2000b, Hodson 1994; H. Rose, 1994b; Taylor & Cobern, 1998). This work includes the constructivist movement (Cobern, 1998a, 1998b). As well as key works from Science and Technology Studies (STS) (Aikenhead, 1994a, 1994b; J. Solomon, 1993, 1994a, 1994b; J. Solomon and Aikenhead, 1994;), Science, Technology Studies and the Environment (STS-E) (Aikenhead, 1998; Hungerford, Bluhm, Volk & Ramsey, 1998) we also see increasing work in the nature of science movement in science education (Matthews, 1994, 1998a; McComas, Clough & Almazroa, 1998). There is a large body of literature on the development of scientific concepts in children (Carey, 1985 (in Gunstone, p299 in Millar et al, Posner et al in Hewson and Lemberger, p110 Millar at el, Stigler and Hiebert, 1999, Bowden and Marton 1998, Ireson p83 in Behrendt) although these areas of research rarely coincide and the latter work assumes that single correct 'expert' conceptions must be developed in children. My own work demonstrates that 'negotiation' of multiple conceptions of engineering 'facts' is necessary to help students grapple with complexity (Baillie et al, 2002, Baillie, 2003a). However, very little theoretical work has been carried out within the area of engineering education and even less on the potential influence of STS studies on engineering education. There is practical know-how currently held within the experience of the few STS folk who do teach engineering students but not much dissemination of this experience. Many engineering students simply take required elective courses on social sciences with very little interest and see no relevance or connection to their own chosen career path.

My own attempts to help first year students engage with difficult social concepts has been met with resistance by many students. I have used qualitative studies and two theoretical works to explore the reasons for this. It seems clear when looking at the work by Meyer and Land (2003a,b)) that my students are experiencing the concepts to be learned in as *alien (counter intuitive to their own experience of the world)*, and *inert (irrelevant to their current needs)*…and against their *tacit* understanding of what engineering is.The interdisciplinary work also bring with it *troublesome* language and even though many of them are unaware of this they find the concepts challenging to understand.

The blocks to knowledge development highlighted in my previous own work (Baillie, 2002, 2003a,2004) are also present:

thought collectives and blinkered perceptions – the new knowledge does not fit with students understanding of the needs of engineers
belief system – students will have difficulty exploring areas such as 'diversity' and 'social impact' when they have only experienced one small part of one community. They will tend to take on their parents/schools values and have not yet formulated their own world view.
negative environment – students will not be able to learn if they are not getting support from other courses/teachers/former students

Paulo Friere (2003) proposes that education should be a process through which people 'develop their power to perceive critically the way they exist in the world with which and in which they find themselves: they see the world not as a static reality but as a reality in process, in transformation (p 69). We want to find ways to facilitate students' ability to ascertain technological needs in diverse social, political, and economic contexts. One attempt to address students' 'social responsibility' is evident the 'service learning' paradigm that is becoming increasingly popular in the United States. The National EPICS (Engineering Projects in Community Service) Program is 'a consortium of universities across the country practicing the EPICS model founded at Purdue in 1995. These programmes are explicitly intended to develop design skills in undergraduate engineering students, and to bring 'affordable engineering expertise to community service' (EPICS 2004). The main problem with this model is that it is not based on a participatory process in which communities have significant input into technological decision-making. Community members are instead placed in the role of 'client' or 'consumer'.

The theoretical underpinnings for our pedagogical framing derive from phenomenography (Bowden and Marton, 1998). The focus of interest is in learning: the learning of qualitatively different ways of seeing the world, ways of making sense of the world and acting within it. Empirical phenomenographic research on learning claims to take a 'second-order perspective' - exploring the relation between the learners and the phenomenon being learned and tries to do this from the perspective of the learners. The object of the research is not to describe the relationship between the individual and the phenomenon but the variation in the relation between a collective of individuals and the phenomenon. The outcome is not a series of case studies but a description of the ways of experiencing on a collective level, catching the essence of the variation. There are four methodological streams of relevant educational research : *action research, collaborative enquiry, transformational learning* and *phenomenography. Action research* is a cyclical process of planning, acting, observing and reflecting. Action research emancipates the practitioner from constraints of assumption, coercion and ideology (Carr and Kemmis 1986). *Learning as transformation* (Mezirow, 2000) requires reflective discourse as dialogue for common understanding, involving a critical assessment of assumptions and emotional intelligence (Goleman, 1995). 'Transformation theory's focus is on how we learn to negotiate and act on our own purposes, values feelings and meanings rather than those we have uncritically assimilated from others – to gain greater control over our lives as socially responsible, clear-thinking decision makers' (Mezirow, 2000 p8). The application of transformative learning in practice is relatively rare, however and applications in areas of technical studies even more so. Hodson (2003) proposes the use of action research aligned to community involvement but no such teaching practice is reported. Taylor (Mezirow, p 315) reports on studies in both secondary and tertiary education in which intensity of experience, risk and personal exploration are required of both teacher and student.

'The best way to get students to respect a plurality of views is when they become familiar with one or two and get the experience of standing somewhere else (gestalt switch)..'if you never move then you never realize the validity of things you are being told' (Steve Sturdy, 2005)

We need to help faculty and Faculties to take the risk and help students experience 'otherness'. They can then make up their own minds about what to do with their new knowledge. It is our students who will create the future of engineering and it is our students who can help engineering to make a difference to the environment, to world poverty and to freedom for all people. Let us think together and support each other in the search for a better future.

Key questions that we feel need to be addressed are:

What dimensions of socially just engineering practice can be identified?
What is the potential of engineering to place social justice at its centre?

What does engineering look like which contributes to social justice? What do these engineers do and what does their organization look like? What drivers are there for current engineering practice?
What examples exist that can be framed as learning objects?How can we learn from the historical examples of the relation between engineering and society?What political, social and economic frameworks support a socially just engineering practice?What effect does globalization have on the potential of engineering for social justice? How do engineering organizations put social justice at the centre?Under what conditions does engineering practice lead to socially just outcomes?

How do we transform the education of engineers to bring us closer to this practice?

How can the economic, social and ecological consequences of alternative technologies and technological pathways best be embodied in engineering education – new approaches to interdisciplinarity?

What sorts of organization structures, pedagogical practices, technologies in curricula promote a transformative learning process within engineering and within communities that helps develop socially just graduate engineers? What examples exist that can be framed as learning objects?

How can we set up participatory frameworks for communities to negotiate with engineering practice?

How do we set up frameworks that enable communities to negotiate with engineering practices as they develop, rather than being simply subject to apparently apolitical technological imperatives?

How can engineering contribute to a social / technological framework which address the needs of all of the members of local, national, and global communities?

How do future engineers find out what a community's technological needs are? How can this be done more effectively, inclusively, and fairly?

How can we best facilitate community engagement as part of a transformative learning process within engineering education, and within broader communities, that helps develop an engineering practice which is socially just?

Key Objectives of an emerging network

To examine the relationship between social justice and engineering.
To explore pedagogical processes that promote an engineering practice which is socially just.

Desired Outcomes

- To develop a Global Network of which will link researchers and practioners in different disciplines and organizations
- To develop partnerships with community groups and mechanisms of engagement in a social needs based analysis of engineering practice
- To create guidelines for embedding education for social justice in engineering programmes and to engage Engineering faculty to pilot and evaluate such programmes
- To contribute to an increased awareness of how engineering is implicated in broadly social, economic and political structures.

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