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Towards an Integrated Approach to Engineering Ethics

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TOWARDS AN INTEGRATED APPROACH TO ENGINEERING ETHICS

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Abstract: There is an increasing diversity in approaches to teaching engineering ethics due to increasing dissatisfaction with the dominant approach which uses case studies focused on moral dilemmas confronting individual engineers. There has been a demand for a greater consideration of the organisational and social context in which engineers work and for a shift in focus from micro ethics issues concerning individuals to macro issues of concern to the engineering profession. Further, there has been a demand that engineers focus on societal decision making about technology and their role in policy development. Drawing on the work of the American sociologist George Ritzer, which focuses on micro/macro integration and the subjective and objective dimensions of sociological analysis, this paper provides a framework for understanding different approaches to engineering ethics. In moving towards an integrated approach, it is argued that a key issue confronting engineers is how to change the economic and social context in which they work so that it enables rather than constrains the development of sustainable engineering solutions. It is also argued that an integrated approach should focus on integrating the different levels of analysis into accounts of ethical issues.

Keywords: Engineering ethics, macro ethical issues, sociology, sustainable development, agency-structure

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1. INTRODUCTION

A recent review (Colby and Sullivan 2008) of the provision for engineering ethics (EE) teaching to US undergraduates concluded that provision for ethics education is inadequate (p. 334), discussion of cases is the most prevalent means of teaching, and that "the broad public purposes of engineering receive little attention" (p.330). The review suggests that "in developing educational efforts to foster ethical development, it is helpful to think about the goals in broad terms" (p.335).

Colby and Sullivan have joined a growing list of scholars who have argued for the broadening of EE arising from dissatisfaction with what can be called the individualistic approach (Conlon and Zandvoort 2009). Various alternatives have been suggested including a demand to focus on macro issues (Hekert 2001), to use an approach based on social ethics (Devon and Van De Poel 2004) or aspirational ethics (Bowen 2009). Others call for a fuller engagement with Science, Technology and Society (STS)[1] studies (Bucciarelli 2008, Herkert 2006, Lynch and Kline 2000) or the philosophy of technology (Son 2008). Further, Mitcham (2009) has identified a "policy turn" in EE which seeks a focus on action to transform institutional arrangements and policy directives as they affect engineering practice. I have argued for such

[1] STS is the study of the interrelationship between technology and society. STS focuses on a range of issues including the relationships between innovations and society, and of organisational culture and risk.

a focus (Conlon and Zandvoort 2009) and that it is particularly important in light of the demand that engineers practice and promote the principles of sustainable development (SD). This will require the profession to influence change in "social, political, economic, and institutional paradigms…thus increasing…our ability to move in sustainable directions" (Donnelly and Boyle 2006 p.153).

All of this presents quite a challenge to those attempting to integrate EE into engineering programmes. Given a divergence in approaches it is necessary to develop tools to understand these different approaches and how they might relate to each other. This may allow us to explore the possibilities for developing an integrated approach and set out more clearly what is required to address the inadequacies in the dominant approach.

In what follows different approaches are analysed using a framework derived from the sociologist George Ritzer. Sociology is a multi-paradigm discipline and Ritzer (2001) wants to move towards an integrated approach. In doing so he has sought to map out different approaches to social analysis as a first step in moving towards integration. I think this framework can be used to look at different approaches to EE. I proceed as follows. First, Ritzers's framework is outlined. It is then applied to analyse different approaches to EE. The conclusions focus on the implications of this analysis for an integrated approach and for the EE curriculum.

2. PARADIGMS IN SOCIOLOGY

Drawing on Kuhn's work on scientific paradigms Ritzer (2001) argues that sociology is a multi-paradigm discipline. This has lead to confusion for those approaching the discipline but also to partial explanations of social phenomena as different paradigms focus on different questions and modes of inquiry. He defines a paradigm as "a fundamental image of the subject matter within a science. It serves to define what should be studied, what questions should be asked, how they should be asked, and what rules should be followed in interpreting the answer obtained" (p.60). Ritzer provides a framework for distinguishing different paradigms as a basis for developing an integrated paradigm (Figure 1).

	Macroscopic		
Objective	**i. Macro-Objective:** Examples include society, law, bureaucracy, technology and language	**ii. Macro-subjective:** Examples include culture, norms and values.	Subjective
	iii. Micro-objective: Examples include patterns of behaviour, action, and interaction	**iv. Micro-subjective:** Examples include the various facets of the social construction of reality	
	Microscopic		

Fig 1: Major levels of social analysis

Source: Ritzer (2001 p.93)

This framework is based on four different levels of analysis which emerge from the interaction of two social continua: the macro/micro and the subjective/objective. The macro/micro refers to the magnitude of social phenomena ranging from whole societies to individual action. The objective/subjective distinction refers to whether a phenomenon has a real material existence (e.g. bureaucracy) or exists only in the realm of ideas and knowledge (e.g norms and values). Based on the interaction of these two continua, Ritzer identifies four levels of social analysis as set out in Figure 1.

What Ritzer is doing here is setting out the elements of an integrated approach to explaining social phenomena. In identifying different levels of analysis he is not implying that the social world is divided into these levels. This is simply one way of thinking about the social world and the ways sociologists have approached it. His argument is that an integrated approach must deal with the four levels of analysis: the structure of society, its culture and values, patterns of behaviour and interaction and the consciousness of individuals. An integrated approach focuses on the four levels and "the dialectical relationship…between them" (p.94).

Given the growing dissatisfaction with the individualistic approach to EE and the demand for a greater focus on macro issues, Ritzer's framework provides a useful tool for both analysing current approaches and developing a more integrated one. Herkert (2005) argues that a framework for linking micro and macro EE issues is missing and suggests that a focus on the role of professional bodies may be one approach to developing an integrated framework.

Ritzer's framework is useful given the view that a shift to the macro level leaves no role for individual engineers in ethical decision making (Son 2008). Ritzer's highlights the importance of both micro and macro levels of analysis and their integration and encourages us to consider not only how the social structure affects what people do but also how what people do affects the social structure (2001 p.96). A more integrated approach may allow us to focus on the relationship between social structure and human action and the manner in which structures both constrain and enable action.

3. PARADIGMS IN ENGINEERING ETHICS

Ritzer's framework can be used to look at different approaches to EE (Figure 2).

	Macroscopic		
Objective	**i. Macro-Objective:** Focus on social, economic and political structures and public policy	**ii. Macro-subjective:** Focus on goals and values of the profession	Subjective
	iii. Micro-objective: Focus on organisational culture and processes and the ability of engineers to prevent the normalisation of deviance	**iv. Micro-subjective:** Focus on consciousness of individual engineers: their ability to identify and solve ethical dilemmas and their ethical will power	
	Microscopic		

Fig. 2 Levels of analysis in engineering ethics

Different paradigms do exist and my focus here is on capturing the fundamental image of the subject as presented by each paradigm. Using Ritzer's framework Figure 2 sets out what I see as four distinct approaches. The following sections will briefly discuss (in reverse order) each paradigm. I will conclude with some the implications for developing an integrated paradigm for the EE curriculum.[2]

4. PARADIGM IV: MICRO SUBJECTIVE

I will call this approach the individualistic approach (Conlon and Zandvoort 2009) as the main focus is on the consciousness and commitment of individual engineers and their ability to identify and resolve ethical dilemmas (Shuman et al. 2004). This approach focuses narrowly on the ethical commitments of individuals, uses simplified case studies to "train" students to be sensitive to and resolve ethical dilemmas, and sees whistleblowing as a key device for ensuring that engineers can remain true to their ethical codes. Conlon and Zandvoort (2009) have identified key features of this approach.

There is an almost exclusive focus on individuals who are facing a dilemma and from whom an ethical decision is expected involving a challenge to the interests of the organisation in which the engineer works. A key objective is to improve ethical will power.

Codes of ethics are assumed to be the principal source of rules that guide ethical decisions. If for some reason elaboration of the rules provided by the ethical codes is considered necessary, this approach falls back on traditional moral philosophy for help. This focuses on small-scale human interactions, while ignoring the ethical problems of multi-actor situations that frequently arise within the context of engineering and technology.

There is an assumption that "win-win" or "creative middle way" solutions, where one must choose among two or more conflicting morally important values, always exist and can be implemented by individual engineers.

Key problems with his approach include[3]:

1. The assumption that win-win solutions exist for ethical problems that engineers encounter and that individual engineers can implement their proposed solutions. Implementation of their solutions may not be within the capacity of individual engineers as they may require changes to the context in which they work. The scenarios used do not faithfully reflect how engineers actually practice engineering. In focusing solely on an individual agent's possible courses of action, these scenarios and exercises not merely oversimplify, but they are uninformative about the social, organisational and political complexities of practice (Bucciarelli 2008). A related point is that the focus on clashes of interest between management and engineers means that engineers own practices are not subject to critical examination. The assumption is that engineers need to be emboldened to resist amoral managers (Lynch and Kline 2000).

2. It diverts attention from the macro-ethical problems of the profession (Herkert 2001, 2005). Herkert argues that engineers should collectively be involved in debates over

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[2] There are two methodological issues which might arise here. First there is the issue of how many levels of analysis there should be and secondly the extent to which each approach can be seen to be an integrated paradigm. In this short paper its not possible to give extended coverage to these issues other than to say that the framework offered allows me to capture what I see as essential differences between approaches to EE. It is the case that within some quadrants there are more coherent approaches on offer.

[3] Rather than provide a long list of references here I refer readers to Conlon and Zandvoort (2009) which contains an extensive bibliography.

public policy regarding the development and use of technology. Paradigm IV though is about providing students with an understanding of the nature of engineering ethics: "the value of engineering rather than the values of an ethical engineer" (Shuman et al. 2004). A shift to a focus on macro issues requires that engineers reflect on the goals of engineering which should be realised through engineering practice and public policy.

5. PARADIGM III: MICRO OBJECTIVE

In light of these deficiencies some have called for alternative approaches to EE. In other to address the failure of Paradigm IV to adequately address the context of engineering practice some have argued that EE should be informed by Science, Technology and Society (STS) studies (Lynch and Kline 2000, Kline 2001, Bucciarelli 2008).

Paradigm III tend to focus on the question as to why accidents happen. The focus is on organisational culture and processes with exemplary work being Vaughan's (1996, 2008) analysis of the Challenger disaster. Her analysis emphasises institutional logics and the manner in which patterns of behaviour develop and become institutionalised within organisations. In the case of the Challenger Vaughan shows how risk came to be redefined leading to a number of launches with a flawed design. This led to what she calls the "normalisation of deviance" within the network of organisations supporting the Shuttle programmes.

Lynch and Kline (2000) draw on Vaughan's analysis to argue for a focus on the detail of engineering practice in EE and the role of organisational culture and processes. There is a recognition that most engineers operate in an environment where their capacity to make decisions is constrained by the corporate or organisational culture (p.210) The aim is "to explore how engineers can learn to identify features of their everyday practice that potentially contributes to ethically problematic outcomes before clear-cut ethical dilemmas emerge" (p.196). An onus is placed on engineers to exercise imagination to develop strategies to prevent these problematic features from developing in their own practice (p. 202).

Lynch and Kline are keen to avoid what they see as simplified explanations of accidents as resulting from amoral managers responding to production pressures on their organisation. They also want to move away from the idea that ethics dilemmas only arise from clashes between engineers and these amoral managers. While this approach can be welcomed in moving away from simplified case descriptions lacking their organisational and social context it is not without problems.

Firstly, although Vaughan pays considerable attention to the wider economic and political environment in which NASA operated and the way it facilitated the normalisation of deviance and "displaced safety and deference to the expertise of working engineers" (2008 p.74, 1996 p.389) Lynch and Kline's focus is mainly on the organisational culture. It is important to look at the interrelationship between internal organisational processes and factors in the wider environment such as the level of competition. This is not to argue that production pressures have a direct effect on the actions of managers but that they must be factored into the analysis: "the tension between safety and profit is a matter of degree, and the relationship will be different in different organisations" (Edward and Wajcman 2005 p.169). Therefore what happens at the workplace cannot be seen to be independent of wider forces in society.

Secondly in focusing on the issue of organisational culture they neglect the issue of power. The Challenger case involves an "extraordinary display of power" that overcame the engineers who opposed the launch (Perrow 1999 p.380). Thus the capacity of organisation members to challenge dominant cultural scripts assumes significance (Edwards and Wajcman 2005). Lynch and Kline (2000) fail to adequately specify how engineers who become aware of the normalisation of deviance are to change organisational practice. They (p.199-200) dismiss those who consider the role that engineering professional bodies, codes of ethics, trade unions, lawyers and regulatory agencies can play in bolstering responses to moral problems. Legal requirements may help engineers to resist managerial pressure (Coeckelbergh 2006) and safety levels may be high where safety is taken up as a trade union issue. It is important to examine the range of organisational and cultural resources available to engineers and these may be generated outside the organisation.

In considering Lynch and Kline's approach Swierstra and Jelsma (2006), argue that in "modern technology projects" the necessary conditions for individual moral agency are lacking and that the picture painted by Lynch and Kline is far too rosy. They call for "an institutional ethics" (2006 p.312) and a focus on the relationship between individual moral agency on the one hand and on the individual's enabling and constraining environment on the other. It is both necessary and possible to influence the institutional environment of engineers so as to enable and stimulate them to behave responsibly (see also Winner 1990).

6. PARADIGM II: MACRO SUBJECTIVE

In light of these criticisms of Paradigms IV and III there is a requirement to widen our focus and examine the role of macro issues in EE. Herkert (2001, 2005, 2006) calls for engagement with STS to broaden EE to include discussion of public policy issues of relevance to engineers (2006 p.415). Son (2008) has argued that the shift of focus to the macro level requires, in the first instance, a focus on the goals of engineering. What values should engineers cherish and what is their idea of the good society? This is the basis of paradigm II.

As a key issue for this paradigm is consideration of the goals of engineering, proponents have called for an engagement with the philosophy of technology. Son (2008) has argued that a shift to a macro focus should lead to a questioning of the goals of engineering or current forms of technological development (p. 413, see also Winner 1990). This would seem particularly important in light of the increasing commitment of the profession to SD. This requires that engineers commit to meeting vital human needs, promoting both intra and intergenerational equity and public participation in decision making about technology (Mulder 2008). It also means that engineers reflect on their understanding of social equity and public participation.

In a recent publication, Bowen (2009) calls for an "aspirational ethics". He makes a clear distinction between ethics, the "aims of a life that can be regarded as good" and morality, "the norms that provide specific articulation of these aims" (p.6). He argues that EE has focused on morality. As a result, engineers have to a significant extent forgotten that their primary objective is the promotion of human well being (p.3). What is needed is the development of a genuinely aspirational ethical ethos which prioritises human flourishing through contributing to human well being.

Drawing on Mac Intyre's *After Virtue,* he argues that engineers have "mistaken the external goods of the practice (mainly wealth and engineered artefacts) for the real end of the practice (which is human well being)"(p.12). This has led to an imbalanced prioritisation in engineering of technical ingenuity over helping people. He contrasts the failure to provide the world's population with safe drinking water with spending on weapons and the development of military technology. Bowens is a version of virtue ethics which correctly argues that the goals of engineering are critical in determining which virtues engineers should possess. Virtues assume significance in the context of an aspirational ethos which promotes human flourishing (pp.75, 78). He highlights the importance of engineering institutions supporting virtues in practice.

Bowen identifies the key problem in engineering as the focus on technical ingenuity rather than human flourishing and seems to suggest two reasons for this. Firstly, drawing on the work of the philosopher Levinas, there is the structural problem in that engineers lack proximity with the users of technology. As technological systems have become more complex and global it's more difficult for engineers to interface with users. Therefore organisations should be restructured to bring engineers closer to their customers (p.97).

Secondly, he argues that engineers have not engaged sufficiently in ethical analysis of their activities (p.3), that engineers need to adopt a positive way of life (p.74) and take responsibility for the outcomes of their activities (p. 26). An aspirational approach will stimulate a change in attitudes so as to promote the personal ethical responsibility of every engineer (p.92). A person who "genuinely possesses a virtue would be expected to manifest it through the range of his or her activities" (p.79).

Bowen's approach is useful in reminding engineers of the importance of prioritising people's needs. As Smart(2001) has said, about the work of Levinas, the demand to focus on our responsibilities to others assumes critical importance in a context where "an increasingly global neocapitalism with a culture of individualism has promoted self-fulfilment as the primary preoccupation and produced moral indifference as a consequence" (p.518). It is also the case that such a culture has promoted the commodification of everything including vital resources such as water (Petrella 2001).

The main emphasis for Bowen is on the culture of engineering and the development of an aspirational ethos amongst engineers but there is no discussion of power and no engagement with what has been called the captivity of engineering: "most engineers work within a management structure dominated by the requirement to provide profitable operation of the consumer culture. What engineering is done…is therefore determined by the wishes of the patron expressed through managerial agenda" (Holt 2001 p.498). This has generated a key contradiction for engineers as they struggle "to attain professional autonomy and define standards of ethics and social responsibility within a context of professional practice that demanded subservience to corporate authority" (Noble 1977: 35). A focus on the context in which engineers work and how action at the level of society can enhance their capacity to promote social responsibility is the focus of Paradigm I.

7. PARADIGM I: MACRO OBJECTIVE

At the heart of this paradigm is the demand of Zandvoort et al. (2000) that engineers must accept that they must play an active role in helping to reshape the broader context from which ethical problems arise "whenever that may be necessary" (p.297). This is necessary to help engineers to meet their ethical responsibilities particularly in relation to safety but also to facilitate the attainment of the goals of engineering particularly in the area of environmental protection and SD. In both cases regulation is seen to enhance the capacity of engineers to promote social responsibility and enhance human welfare. This is not to argue that change in regulatory frameworks resolves all issues but rather that "structural change makes certain actions seem necessary while others seem impossible" (Dietz and Burns 1992 p.192, see also Coeckelbergh 2006).

A focus on safety can be seen in De George's (1981) analysis of the Pinto case. His focus is on changing organisations and the laws that regulate them. This he argues would change the approach to safety in many organisations. Taking a wider focus Zandvoort (2005) has proposed wide ranging changes to legal systems to enable socially responsible behaviour in engineering and the promotion of sustainability. But other changes are also necessary. In order to move towards sustainability far reaching social, cultural, economic, political, legislative, regulatory, and institutional changes are required (Donnelly and Boyle 2006, see also Beder 1996, 1998).[4] This means that engineers must engage with public policy and the barriers to change.

Some have argued that there are contradictions between the goals of sustainability and current political priorities. Government policies centred on privatisation, deregulation and the promoting of competition are undermining progress in meeting vital needs such as the provision of clean water (Petrella 2001). Further the promotion of overconsumption undermines efforts to promote more sustainable patterns of consumption and production. Woodhouse (2001) calls on engineers to struggle against overconsumption. Others have argued for long term "thinking to take the place of the present consumer driven fast profit generating…system" (Weiler 2001 p.511). Short term thinking associated with the business and political cycles can undermine the effective application of the Precautionary Principle (EEA 2001) a tool for engineers in avoiding and managing risk and environmental damage

All of this generates a requirement to focus on the organisation of production and consumption and how public policy and patterns of regulation can lead to more sustainable outcomes (Donnelly and Boyle 2006 p.151, Beder 1996) Beder (1998 pp.175-6) shows how laws imposing "previously non-existent constraints" can become "inducement mechanisms" for technological innovations which protect the environment.

But problems remain particularly in moving from one technological system to another. STS scholar Thomas Hughes (1989) has used the concept of "technological momentum" to understand the manner in which technological systems get "locked in" making it hard to change them. In Hughes view systems incorporates both technical and social elements including technological artefacts, organisations, actors, regulatory agencies, laws, education and natural resources. As a technological system grows it develops a mass which is made up of institutions and people who have a vested interest in maintaining it. Mature systems have a quality similar to inertia. The development of the system is on conservative lines and radical change is resisted because it threatens the interest of system actors: "Concepts related to momentum include vested interests, fixed assets and sunk costs" (Hughes 1989 p.77). That is

[4] The Declaration of Barcelona, adopted in 2004 at the First Engineering Education for Sustainable Development Conference, called on educators to prepare engineers to "Participate actively in the discussion and definition of economic, social and technological policies, to help redirect society towards more sustainable development" The full Declaration is available at http://eesd08.tugraz.at/?show=declaration

not to say that change is impossible but that a variety of system components, not just the technical components, must be subject to the forces of change.

Scrase and Mac Kerron (2009) have used the concept of "lock in" to analyse why renewable energy has not been more widely adopted. They make the point that the high capital intensity, longevity and fuel specificity of most capital assets are barriers to change which are compounded by the policies of governments committed to free market ideology and associated investment structures. They point to International Energy Agency estimates that $11 trillion in investment is needed between 2005 and 2030 in the worldwide electricity system and argue that "if we are to move with urgency on to a low carbon pathway, government needs to take a more interventionist stance and not automatically endorse competition"(p. 100).

This suggests that engineers need to be able to evaluate public policy and make proposals for change. They also need to understand the process of technical and policy change including the social, political and economic factors that constrain or facilitate the movement towards sustainable social practices and the use of sustainable technologies.

8. CONCLUSION

This brief review of different approaches to EE suggest there are a wide range of factors to be taken into account in considering the capacity of individual engineers to practice engineering in a manner that is socially responsible and promotes the goal of sustainability. It can be suggested that an integrated approach would incorporate the four levels of analysis into the consideration of any ethical problem and examine both the values and commitments of engineers but also their capacity to act on these values and commitments. The real issue is not, as Herkert has posed it, how to integrate macro issues into the teaching of engineers but rather to develop an approach which integrates the different levels of analysis and takes adequate account of the commitment and power of engineers to pursue such goals as safety, sustainability and the enhancement of human welfare. The focus then is on "which *ends, principles, and conditions* deserve not only our attention but also our commitment" (Winner 1993 p.374 emphasis added).

Rather than trying to neatly demarcate what is or is not a macro or micro issue it might be better to use the sociological distinction between structure and agency (Conlon 2008) as a basis for integrating macro issues into the analysis of engineering practice: "macro/micro debates have largely become debates about the relationship of agency and structure" (Barnes 2001 p.344). It is not always clear that macro and micro issues can be easily distinguished. Herkert (2005) has, for example, identified the design of safe products as a micro issue. But the safety of engineering products and processes is affected by the attitudes and practices of engineers, the organisational culture, the regulatory regime and public policy, which includes policy on product liability which Herkert identifies as a macro issue. A focus on macro issues does not mean that micro issues disappear but rather highlights the need to widen the analysis to look at how the broader environment enables or constrains the capacity of engineers, for example, to design safe products. Such an approach accords with the need identified by those focused on EE and the design process to consider the relationship between individual actions of designers and their institutional and social environment (van de Poel and Verbeek 2006 p.224). This would also require us to look at how individual engineers and their professional bodies seek changes in their environment. This requires a focus on societal decision-making about technology and the role of professional bodies within that process.

Such an approach will be based on multidisciplinary inputs from a diverse range of disciplines. The above analysis suggest that rather than just heading to the philosophy department engineering educators will need to consider the role of the sociology, politics, history and law departments in their efforts to educate socially responsible engineers. This may raise questions as to whether the requirements for teaching ethics can be contained within single and discrete modules or whether engineering programmes should be more fully redesigned to adequately address the challenge of educating socially responsible engineers.

Reference List

Barnes, B. (2001). The macro/micro problem and the problem of structure and agency. In G. Ritzer and B. Smart. Handbook of Social Theory. Sage. London. 339-52.

Beder, S. (1996). Towards an environmentally conscious engineering graduate*, Australasian Journal of Engineering Education.* 7(1). 39-45.

Beder, S. (1998). *The new engineer.* Sydney: Macmillan.

Bowen, W.R. (2009). *Engineering ethics: Outline of an aspirational approach*. London: Springer.

Bucciarelli, L. L. (2008). Ethics and engineering education. *European Journal of Engineering Education,* 33(2), 141- 149.

Coeckelbergh, M (2006) Regulation or responsibility? Autonomy, moral imagination and engineering, *Science, Technology and Human Values*, 31 (3) 237-22260

Colby, A. and Sullivan, W.M. (2008). Teaching ethics in undergraduate engineering education*, Journal of Engineering Education*, 97 (3), 327-338.

Conlon, E. (2008). The new engineer: Between employability and social responsibility. *European Journal of Engineering Education,* 33(2), 151-159.

Conlon, E. and Zandvoort, H. (2009) Broadening Ethics Teaching in Engineering: Beyond the Individualistic Approach, Paper to *SEFI Annual Conference, Rotterdam,* July 2009.

De George, R.T. (1981). Ethical responsibilities of engineers in large organizations: The Pinto case. *Business & Professional Ethics Journal,* 1(1) 1-14.

Dietz, T. and Burns, T.R. (1992). Human agency and the evolutionary dynamic of culture. *Acta Sociologica,* 1992, 35 , 187-200.

Donnelly, R. and Boyle, C. (2006). The Catch-22 of engineering sustainable development. *Journal of Environmental Engineering,* February 2006, 149-155.

Edwards, P. and J. Wajcman (2005). *The politics of working life.* Oxford University Press.

European Environment Agency (2001) *Late lessons form early warnings: the precautionary principle 1896-2000*, Copenhagen.

Herkert, J.R. (2001). Future direction in engineering ethics research: Microethics, macroethics and the role of professional societies. *Science and Engineering Ethics*, 7, 403-414.

Herkert, J.R. (2005). Ways of thinking about and teaching ethical problem solving: Microethics and macroethics in engineering. *Science and Engineering Ethics*, 11(3), 373-385.

Herket, J.R. (2006). Confession of a shoveler. *Bulletin of Science, Technology and Society*, 26 (5), 410-418.

Holt, J.E. (2001). The status of engineering in the age of technology, *International Journal of Engineering Education,* 17 (6), 496-501.

Hughes, T. (1989) . The evolution of large technical systems. In W.E. Bijker, T.P Hughes and T. Pinch. The Social Construction of Technical Systems. Cambridge MA: MIT Press.

Kline, R. (2001). Using history and sociology to teach engineering ethics. *IEEE Technology and Society,* 20(4), 13-20.
Lynch, W.T. and Kline, R. (2000). Engineering practice and engineering ethics. *Science, Technology and Human Values*, 25 (2), 195–225.
Mitcham, C. (2009) A historico-ethical perspective on engineering education: from use and convenience to policy engagement, *Engineering Studies*, 1(1), 35-55.
Mulder, K. (2008). *Sustainable development for engineers*, Sheffield: Greenleaf.
Noble, D. (1977). *America by design.* Oxford University Press.
Petrella, R. (2001) Globalisation and ethical commitment. In P. Goujan and B.H. Dubreuil, Technology and Ethics, Peeters: Leuven, 413-21.
Ritzer,G (2001) *Explorations in social theory: from metatheorizing to rationalization*. London: Sage.
Scrase, I. and G. Mac Kerron (2009), Lock-In. In Scrase, I. and G. Mac Kerron. Energy for the Future. Basingstoke: Palgrave.
Shuman, L.J., Sindelar, M.F., Besterfield-Sacre, M., Wolfe, H., Pinkus, R.L., Miller, R.L., Olds, B.M., Mitcham, C. (2004). Can our students recognize and resolve ethical dilemmas? *Proceedings, ASEE Annual Conference and Exposition.* 2004
Smart, B. (2001). Sociology,morality and ethics: On being with others. In G. Ritzer and B. Smart. Handbook of Social Theory. Sage. London. 339-52.
Son, W.C. (2008). Philosophy of technology and micro-ethics in engineering. *Science and Engineering Ethics*, 14(3), 405-415.
Swierstra, T. and Jelsma, J. (2006). Responsibility without moralism in technoscientific design practice. *Science, Technology and Human Values,* 31(3), 309-332.
Van de Poel , I. and Verbeek, P.P. (2006) Ethics and engineering design, *Science, Technology and Human Values*, 31 (3) 223-236.
Vaughan, D. (1996). *The Challenger Launch Decision.* University of Chicago Press.
Vaughan, D. (2008). Bourdieu and organisations: the empirical challenge. *Theory and Society*, 37, 65-81.
Weiler, R (2001) Sustainability: A vision for a new technical society. In P. Goujan and B.H. Dubreuil, *Technology and Ethics*, Peeters: Leuven, 511-524.
Winner, L. (1990). Engineering ethics and political imagination. In P. Durbin (ed.), Broad and Narrow Interpretations of Philosophy of Technology: Philosophy and Technology. Boston: Kluwer. 53-64.
Winner, L. (1993). Upon opening the black box and finding it empty. *Science, Technology and Human Values,* **18**(3), 362-378.
Woodhouse, E.J. (2001). Curbing overconsumption: Challenge for ethically responsible engineering, *IEEE Technology and Society Magazine,* Fall 2001, 23-30.
Zandvoort, H. (2005). Good engineers need good laws, *European Journal of Engineering Education,* 30(1), 21–36.
Zandvoort, H., Van de Poel, I. and Brumsen, M. (2000). Ethics in the engineering curricula: topics, trends and challenges for the future, *European Journal of Engineering Education,* 25 (4), 291–302.