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Marco, Micro, Structure, Agency: Analysing Approaches 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.

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

1. INTRODUCTION
Colby and Sullivan's [8] review of the provision for engineering ethics (EE) teaching to US undergraduates concluded that provision for ethics education is inadequate, 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).

Various alternatives to a narrow focus on case studies have been suggested including a demand to focus on macro issues [17] or to use an approach based on aspirational ethics [5]. Others call for a fuller engagement with the philosophy of Technology [40] or Science Technology and Society (STS) studies[1] [6, 19, 28]. Further, Mitcham [29] has identified a "policy turn" which seeks to focus on action to transform institutional arrangements and policy directives as they affect engineering. I have argued for such a focus [9] 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 [14].

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 [36] 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 [36] 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 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). 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

[1] STS is the study of the interrelationship between technology and society and how they shape each other.

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.

<table>
<tr><th colspan="4">Macroscopic</th></tr>
<tr><td rowspan="2">Objective</td><td>i. Macro-Objective: Examples include society, law, bureaucracy, technology and language</td><td>ii. Macro-subjective: Examples include culture, norms and values.</td><td rowspan="2">Subjective</td></tr>
<tr><td>iii. Micro-objective: Examples include patterns of behaviour, action, and interaction</td><td>iv. Micro-subjective: Examples include the various facets of the social construction of reality</td></tr>
<tr><th colspan="4">Microscopic</th></tr>
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Fig 1: Major levels of social analysis

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 [18] 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: "being ethical and unethical fades away if one emphasizes a structure that can deal with the macro-level issues" [40]. In a similar vein Davis [11] argues that sociological approaches to EE tend to make decisions seem inevitable as events are seen as linked by social forces rather than by individual decisions.

This does not acknowledge the extent to which social theory has sought to deal with the question of human agency and the manner in which actors, individual and collective, develop the capacity to influence their environment. It is the case that human choice is restricted and confined by social and cultural structures. But these structures can be changed to enable actors to have greater choice. Davis is right to take sociology to task as some forms of sociological explanation treat humans as oversocialised cultural dopes who merely manifest the demands of their society or culture in their actions. If actions are determined at this level then all ethical issues are diluted as human resistance and intervention become futile (See Section 3.2 below). But there are many critics of this approach, one of whom, Margaret Archer, has argued that the key issue facing social theory is to develop frameworks that link structure and action and specify the conditions "under which agents have greater degrees of freedom or work under a considerable stringency of constraint". She argues, correctly, that the structural and cultural properties of society "only emerge through the activities of people and are only causally efficacious through the activities of people" [1].

Ritzer is providing a framework for exploring these issues rather than a substantive theory about the relationship between action and structures. It is useful in highlighting 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. A more integrated approach to EE should allow us to focus on the relationship between social structure and human action and the manner in which structures both constrain and enable action. It may allow us to avoid a moralism which burdens individual engineers with responsibilities that they cannot meet [41] and to better investigate the circumstance which would facilitate the attainment of goals such as enhancing human welfare and sustainability which the profession has set for itself.

3. PARADIGMS IN EE

Ritzer's framework can be used to look at different approaches to EE. Different paradigms do exist and my focus

<table>
<tr><th colspan="4">Macroscopic</th></tr>
<tr><td rowspan="2">Objective</td><td>i. Macro-Objective: Focus on social, economic and political structures and public policy</td><td>ii. Macro-subjective: Focus on goals and values of the profession</td><td rowspan="2">Subjective</td></tr>
<tr><td>iii. Micro-objective: Focus on organisational culture and processes and the ability of engineers to prevent the normalisation of deviance</td><td>iv. Micro-subjective: Focus on consciousness of individual engineers: their ability to identify and solve ethical dilemmas and their ethical will power</td></tr>
<tr><th colspan="4">Microscopic</th></tr>
</table>

Fig. 2 Levels of analysis in engineering ethics

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 and for the EE curriculum.[2]

3.1 Paradigm IV Micro Subjective

I will call this approach the individualistic approach [10] as the main focus is on the consciousness and commitment of individual engineers and their ability to identify and resolve ethical dilemmas [38]. 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. Key features of this approach are [10].

1. 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.

2. Codes of ethics are assumed to be the principal source of rules that guide ethical decisions. It is hence implicitly assumed that these rules are sufficiently clear and free of conflicting elements to be applied to particular cases. 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.

3. 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 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 [10, 26]. 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 [6]. 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 [28].

This approach also diverts attention from the macro-ethical problems of the profession [17] [18]. Herkert argues that engineers should collectively be involved in debates over 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 ethics rather than the values of an ethical engineer" [38]. A shift to a focus on macro issues requires that engineers reflect on and commit to the goals of engineering which should be realised through engineering practice and public policy.

3.2 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 [6] [24] [28].

While those working using Paradigm IV focus on whether individual students can resolve ethical dilemmas those using Paradigm III tend to focus on the question as to why accidents happen. The focus here is on organisational culture and processes with exemplary work being Vaughan's [43] analysis of the Challenger disaster and Lee and Erdmann's [25] "organisational and network" analysis of the Ford Pinto case.

Both works draw on what is called "new institutionalism": a form of organisational analysis which emphasis institutional logics and the manner in which patterns of behaviour develop and become institutionalised within organisations. In the case of the Challenger Vaughan discusses in detail how risk came to be redefined leading to a number of launches with a flawed design. This led to what she calls "normalisation of deviance" within the organisations supporting the Shuttle programmes

Lynch and Kline [28] 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. 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.

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 reinforced the normalisation of deviance Lynch and Kline's focus is mainly on the organisational culture. Changes in the budgetary environment meant that NASA was forced to operate more like a business in which "schedule, budget, following rules and procedures, and allegiance to hierarchy displaced safety and deference to the expertise of working engineers" [40]. Thus her analysis is not only focused at the micro level of the organisation and work groups but at the relationship between the culture of the

[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.

workgroup and the wider economic and political environment in which NASA operated. Indeed Vaughan is sceptical about the possibilities for organisational reform which does not take account of the wider environment (pp.415-22).

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 an unmediated effect on the actions of managers, (for example, worker organisation may constrain the ability of management to cut back on safety), but 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" [15]. 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 there is a danger of seeing organisational actors as social dopes [16] who are merely following the script and neglecting the issue of power. The Challenger case involves an "extraordinary display of power" that overcame the engineers who opposed the launch [34]. Lee and Erdmann say that some engineers reported that those who had reservations about the safety of the Pinto "believed themselves powerless to challenge the prevailing 'acceptable risk' definitions" [25].

Thus the capacity of organisation members to challenge dominant cultural scripts assumes significance [15]. Lynch and Kline [28] 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 [7] 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 [41], 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" [41] and a focus on the relationship between individual moral agency on the one hand and the individual's enabling and constraining environment on the other. It is both necessary and possible to influence the institutional environment of engineers to enable and stimulate them to behave responsibly (see also [47]).

3.3 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 [17-19] calls for engagement with STS to broaden EE to include discussion of public policy issues of relevance to engineers. Son [40] 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 [40] 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: "..engineers will be obliged to reflect on what kind of society is desirable, to produce sound arguments for their ideas, and to conduct and justify their engineering practices accordingly" (p. 413, see also [47]). This would seem particularly important in light of the increasing commitment of the profession to SD.

In a recent publication, Bowen [5] 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. What is needed is the development of a genuinely aspirational ethical ethos which prioritises human flourishing through contributing to human well being. [3]

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, such as respect for life and the public good, assume significance in the context of an aspirational ethos which promotes human flourishing. 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. In a similar vein Moriarity argues that focal engineering is more likely to be practiced in small companies that pride themselves on their human face [30].

Secondly, Bowen 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 [39] has said, about the work of Levinas, the demand to focus on our

[3] Moriarty [30] also calls for a focus on the goals of engineering. He argues that it is not enough for engineers just to focus on justice, safety and sustainability. He calls for a focal engineering the products of which encourage engagement, enlivenment and resonance.

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). But it not clear that he offers a clear path to address the failure to prioritise human need. He neither provides criteria by which human flourishing can be judged nor adequately takes account of the specifically capitalist context in which much engineering takes place: "The problem with an economy in the grip of the capitalist "take" on reality is that everything becomes commodified and human relationships become purely functional and instrumental. An attitude of respect for persons becomes more and more difficult to maintain…(C)apitalism implicates engineering almost totally in its cycle of commodification, production and consumption [30].

The main emphasis for Bowen is on the culture of engineering and the development of an aspirational ethos amongst engineers. There is a danger here of moralism [41]. While engineers *may* be committed to ethical practices it is not always possible to behave ethically. To exercise moral agency, commitment to particular outcomes *is* necessary, but so is the power to achieve these outcomes. To exercise agency actors must have choices, but these are constrained by the physical world, the social structure and the power of other agents [9]. There is no discussion of power in Bowen 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" [20]. 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" [32].

Rising the level of analysis to address macro issues and the broader goals of engineering is not enough unless we address the capacity of engineers to practice engineering in a way that promotes human flourishing. This means changing the structural context in which they work. 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.

3.4 Paradigm I: Macro Objective

At the heart of this paradigm is the demand of Zandvoort et al. [51, see also 26] 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.

It is possible to identify two broad, and overlapping, approaches to changing the environment in which engineers work. The first would seem to accept that the current organisation of production and consumption can be reformed through regulation to give support to engineers who want to practice socially responsible engineering. The second approach questions whether the goals of sustainability and social justice can be met within the confines of current relations of production and consumption. In order to move towards sustainability far reaching social, cultural, economic, political, legislative, regulatory, and institutional changes are required [14].

In both cases regulation and reform is seen to enhance the capacity of engineers to promote social responsibility and enhance human welfare. This means that engineers must engage with public policy and the barriers to change. [4]

An example of the first approach which focuses on safety can be seen in De George's [13] analysis of the Pinto case. Rather than focus on training engineers to be moral heroes he argues that those in EE should be asking "what changes can be made to prevent engineers from being squeezed" (p.10) in the way Ford squeezed them. His focus is on changing organisations and the laws that regulate them. For example, he argues for holding senior executives responsible for accidents and deaths and for strict penalties, including imprisonment, when their organisation is found guilty.

Taking a wider focus Zandvoort [50] has proposed wide ranging changes to legal systems to enable socially responsible behaviour in engineering and the promotion of sustainability. He argues for legal changes which would give the public the right to be informed about technological risks, and introduce a regime of strict liability. He also argues for changes to the laws governing responsibility in organisations and proposes that organisations operate on the basis of 'shares of responsibility' for their activities.

Underlying this work is the recognition that "If the engineers claim for safety have to survive in a context dominated by competition for money and power, regulation with an ethical content may be the engineers life jacket" [7]. It is also the case, as Beder [4] shows, that laws imposing "previously non-existent constraints" can become "inducement mechanisms" for technological innovations which protect the environment.

This might suggest that technological innovation alone can deliver environmental protection and sustainability. Indeed most of the focus in engineering is on evaluating technical reliability and environmental impact [27]. But some have argued that we need a wider focus and 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 [33]. Further the promotion of overconsumption undermines efforts to promote more sustainable patterns of consumption and production [49]. Others have argued for long term "thinking to take the place of the present consumer driven fast profit generating…system" [46].

There is a tension between those who argue that reform can deliver sustainability and those who seek more fundamental change: "Reform is not enough as many of the problems are

[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

viewed as being located within the very economic and power structures of society because they are not primarily concerned with human well being or environmental sustainability" and are "based on the exploitation of most people and the environment by a small group of people" [21]

Taking this as her starting position Riley [35] has called on engineers to oppose neo-liberalism: "Underlying most engineering projects at any scale is an unquestioning acceptance of capitalism and free markets. This often leads to an unspoken or even unwitting acceptance of neoliberal approaches that advantage the United States and other developed countries". In his discussion of the possibilities for an alternative design practice Niusma [31] identifies the capitalist market as a barrier to those who seek to challenge the status quo: " By catering to economically powerful groups, market-led design practices create even more products while leaving the many basic needs unaddressed" (p.21).

This suggests that sustainability requires more than product and process innovation. The focus is on whole system innovation. This places increasing emphasis on the broad context in which engineers work forcing them to consider the politics and economics of technological change and the barriers to such change.

STS scholar Thomas Hughes [22] 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" [22].

This explains why superior technologies with better environmental performance are not being adopted. That is 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 [37] 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. John Law uses the term "heterogeneous engineer" to capture the idea that engineers must master and manage many factors beyond the technical [23].

4. CONCLUSION

This brief review of different approaches to EE suggest there are a number 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 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" [48 emphasis added]. Some issues arise from this.

Firstly, 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 [9] 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" [2]. It is not always clear that macro and micro issues can be easily distinguished. Herkert [18] 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, production pressures 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 [42].

Secondly, the focus in engineering ethics on professional autonomy needs to be considered. A focus on the agency of engineers and the way the environment they work in supports or constrains their capacity to achieve gaols as set by the profession and society requires us to ask who engineers want autonomy from and how will they use such autonomy.

In his discussion of alternative design practices Nieusma [31] says that "Agency refers here to the ability of social actors to act independently of larger structural forces." This seems to confuse agency with autonomy, is somewhat similar to Pavlovic's definition of autonomy as "a relative absence of restrictions on action" [in 12], and suggests that all structural forces have a negative impact on engineering design practice.

This largely negative approach to structural forces would seem to misunderstand what is required to enable engineers to meet the goals of the profession. Throughout this paper reference has been made to the positive role of regulations in enabling engineers who want to promote safety and sustainability. Some who defend professional autonomy are hostile to such an approach: "If the government starts telling physicians how to treat people, or telling preachers what to preach, or telling engineers how to build things then the public loses" [41]. But that's not always so. Changes in building regulations can both increase access for the disabled and improve energy efficiency thus providing gains for the public while enabling engineers committed to universal design and sustainability to implement their designs[5]. Thus the agency of engineers is increased through state intervention. What's at stake is the nature of that intervention and the character of state regulation. It is the case that building regulations in the past did not address the needs of the disabled or promote the goals of sustainability. But changing values in society and social struggles by disability and environmental activists have changed political discourses leading to changes which may now enable engineers to promote social inclusion and sustainability.

Nieusma [31] also has a very narrow view of the extent of change that designers can seek: "designers have no avenue for change outside of specific (narrow) projects in specific (narrow) contexts". Yet as the focus of EE expands, particularly under the influence of STS, engineers will realise that they both have broader collective responsibilities and must engage with other actors in society in order to be more responsible engineers [23]. This opens up the possibility of developing alliances across society with the aim of promoting the kind of change that would enable engineers to attain goals such as safety, sustainability and social justice. [6] This may also curtail their professional autonomy.

Finally, it's quite clear from the literature that there are diverse views on what attaining the goals of safety, welfare, justice and sustainability involves [see 27]. At this point it remains unclear that the profession as a whole is committed to the kind of radical change which sustainability might imply. There is a need for the profession to clarify what, for example, it means by sustainability. In the interim there is a responsibility on those teaching EE to provide students with a sense that change is necessary and possible and that there are alternatives to market based systems which constrain the activities of engineers. Without a sense that there are alternatives agency fails to have any real meaning as outcomes are predetermined. This lends support to those who have argued that a fuller engagement between EE and STS can only come about when STS scholarship involves an explicit normative analysis [19, 23].

In terms of the ethics curriculum all of this requires us to design programmes which address the following questions:

1. What meaning does social responsibility have for engineers both individually and as a profession? What goals and values is the profession committed to and how does it generate commitment to these goals and values?

2. What discretion do engineers have and what criteria do engineers use in solving engineering problems and whose interests do these solutions serve?

3. What constraints stop them acting in a socially responsible manner? Do they have the power to act or does the power of others stop them? How are organisational decisions made and what resources are available to engineers to challenge "unethical" practices?

4. How can constraints be changed to facilitate social responsibility? What changes in public policy, including laws, or social practices are needed and what resources and allies can they call on to help them seek these changes?

5. What alternative models of engineering practice are available other than those located within profit driven and hierarchically organised corporations?[7]

Answering such questions will require 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.

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[5] See [26] for a discussion of the role of technical codes in defining and constraining acceptable engineering practice.

[6] Meiksins and Smith have argue that work humanisation was facilitated in Sweden because Swedish engineers were closely aligned with manual workers and were engaged in a dialogue with social scientists [see 9].

[7] In this context the study of the history of engineering and technology would bear fruit. Consider Nobles [29] description of the emergence of a reform movement in engineering in the USA at the beginning of the 1900s: " In the first two decades of the century a number of engineers began to perceive a contradiction between socially beneficial technological progress and the corporate control of the material and human means to that progress, between the possibilities of science and the demands of profit-making business. They began to question industry domination of their professional societies, to seek public employment in government agencies on all levels, to offer their technical services to labor and radical movements, and to demand more power for themselves as engineers. In all of these efforts they tended to reject the engineering creed that the dollar had the last word, and to shift the balance of engineering priorities from profit to scientific integrity, social betterment and political reform"

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