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# PRACTICAL SKILLS AND TECHNIQUES FOR THE TRANSITION TO A SUSTAINABLE FUTURE, A CASE STUDY FOR ENGINEERING EDUCATION

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**Abstract:** This paper seeks to assess the gap between the visions of sustainable engineering practice with its current reality. A case study involving Energetics Pty. Ltd., a leading Australian multi-disciplinary consultancy specialized in engaging public and private organizations in the development of their responses to climate change and sustainability was conducted based on a staff questionnaire developed following a review of current literature and initiatives on sustainability globally.

The results of the survey indicate that sustainability in engineering practice is still focused on the technical and financial impacts of perceived sustainable solutions. The broader aspects that have been identified as necessary have yet to be achieved in education or practice. The principle reason for this appears to lie in the perception engineers have of their practice and the ability of engineers to communicate effectively with their clients. These have combined to make regulation one of the principal drivers in environmental and sustainability engineering. A sustainability informed ethics paradigm needs to be brought more to the fore to allow engineers to engage with their clients in a more effective manner. Engineers do have the opportunity to be agents of change, but only when they envisage a broader societal role and context for engineering and can communicate effectively with the decision makers within their client organisations.

*Keywords; sustainability, sustainable development, engineering education, ethics.*

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## 1. SUSTAINABLE DEVELOPMENT IN ENGINEERING

The concept of Sustainable Development was brought to prominence by the Brundtland Commission in 1987 where it was defined as “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (WCED, 1987). Since that time the concept has been expanded by governments, business and professional organisations, each having their own particular position given their respective roles in problem formulation and decision making structures. For example, the World Business Council for Sustainable Development views the three pillars of sustainability as “*economic growth, ecological balance and social progress.*” (WBCSD, 2010) Environmental organisations view sustainability as “*improving the quality of life while living within the carrying capacity of supporting ecosystems.*”(UNEP/WWF/IUCN, 1991)

The engineering profession also recognises its unique role in achieving a sustainable society. The 1997 report of the Joint Conference on Engineering Education and Training for Sustainable Development in Paris called for sustainability to be “*integrated into engineering*

education, at all levels from foundation courses to ongoing projects and research” and for engineering organisations to “adopt accreditation policies that require the integration of sustainability in engineering teaching” (JCEETSD, 1997). This has been followed by several initiatives from peak professional engineering bodies around the world who have the authority and responsibility for accreditation of education programmes and the definition of acceptable engineering practice. The following questions arise from a review of these initiatives (see Section 4):

1. How does the view of sustainability, as held by peak engineering bodies, tally with the perceptions of those engaged in transitioning organisations to a sustainable future?
2. How have these principles been communicated through practitioners' education?
3. What aspects of practice are not reflected in these principles?
4. How might these be incorporated into engineering education?

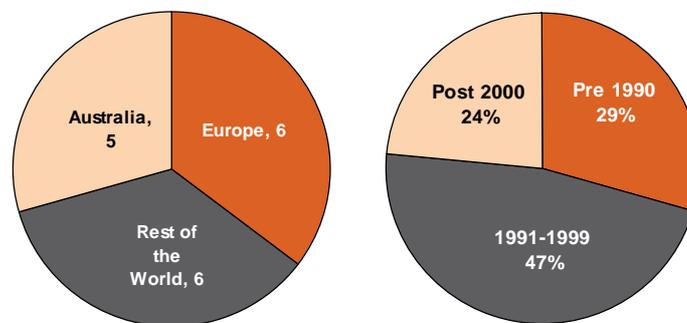
## 2. BACKGROUND OF STUDY PARTICIPANTS

### 2.1 Description of Energetics

Energetics is a leading multidisciplinary consultancy in Australia who has been active in the field of energy management and sustainability for over 25 years. Energetics was founded two years prior to the Brundtland definition of Sustainable Development. The activities of Energetics have changed over the years in line with the changing demands of client organisations with respect environmental compliance and best practice. Energy Management was the focus at the company's inception as cost savings and performance were clients' principal drivers. The deregulation of the electricity and gas markets made understanding energy usage vital to competitive procurement. As the climate change agenda began to assert itself in the market place, the relationship between energy and emissions became increasingly important. It also compelled companies to look at the product or service they provide in the context of its entire supply chain. This brought Life Cycle Analysis to the attention of major companies who wished to understand both the opportunities and risks associated with their product being viewed through the LCA lens. This journey, and Australia's immigrant culture, has allowed the practitioners at Energetics grow to represent a unique range of experience in temporal and geographic terms.

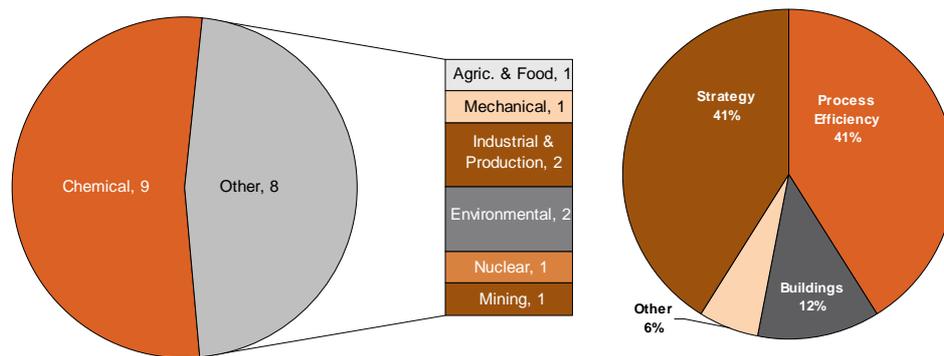
### 2.2 Participants' profile

A total of seventeen Energetics consultants with an engineering background were interviewed as part of this case study. The regions they studied in and era of education are provided in Figure 1.



**Figure 1. Geographical educational background and era of graduation of interviewee cohort**

The participants are graduates of Ireland, France, the UK, the Netherlands, Canada, South Africa, Chile, India and Malaysia. Energetics offers consultancy services across a range of areas including energy procurement, emissions accounting and abatement across commercial building, utilities and industrial sectors. The primary degree of participants (by engineering discipline) and the nature of their work at Energetics are provided in Figure 2. Engineers working for the company tend to focus on the abatement aspects of the business. This is described as process efficiency for all clients other than commercial buildings. More senior members of the company would focus on strategic aspects of abatement, which more junior staff focus on the identification and development of specific abatement opportunities.



**Figure 2. Primary engineering degree & nature of work of participants**

Given the nature of Australian industry, which has a significant resources sector, the majority of the participants are chemical engineers, but a wide range of engineers are represented. Civil engineering is conspicuous by its absence, even though Energetics has been engaged by a variety of infrastructure operators.

#### 4. QUESTION SET DEVELOPMENT

In conducting this case study, it was first necessary to establish what is considered to be sustainable engineering practice. In recent years national and international peak bodies from around the world have proposed principles of engineering practice as it relates to sustainable development/sustainability. These include the Melbourne Communiqué (2001), the Shanghai Declaration on Engineering and Sustainable Development (WFEO, 2004), Engineering for Sustainable Development (RAE, 2005), Sustainability and Engineering in New Zealand - Practical Guidelines for Engineers (IPENZ, 2005), National Guideline on Environment & Sustainability (Canadian Council of Professional Engineers, 2006), Declaration of Barcelona (2004), Protocol for Engineering – A Sustainable Future for the Planet (ASCE/CSCE/ICE, 2006), Engineers Australia Sustainability Charter (EA, 2007) and Guidance on Sustainability for the Engineering Profession (ECUK, 2009). These, plus a number of other publications (Gagnon et al., 2008, Stasinopoulis et al., 2008 and Ehrenfeld, 2009) were reviewed in identifying underlying themes. The following themes emerged from this review:

1. Understanding how engineering decisions impact on a local and global basis
2. Providing cultural, political and social context to engineering design

3. Incorporating information from non-engineering stakeholders into designs
4. Providing an ethical framework for engineering decisions
5. Providing balance in solutions between cost and benefits, both to the client and the environment
6. Identifying qualitative aspects that may be impacted by engineering decisions (heritage, social exclusion, etc.)
7. Participating in problem formulation, not only solutions
8. Applying a Life Cycle Costing or Analysis to proposed designs
9. Regulations – understanding them, applying them and engaging in their development
10. Capacity to explain technical/engineering issues in layman's terms
11. Engaging with non engineering stakeholders in the decision making process/acting as part of a multidisciplinary team
12. Distinguishing between “weak” and “strong” sustainability (the former allows natural capital to be substituted by human made capital, the latter does not (see Gray, 2010))
13. Recognising the importance of finding a pathway towards attaining sustainability (through for example, methods such as “backcasting”) as opposed to reducing unsustainability (through for example, improved eco-efficiency)

These themes formed the basis of a structured and semi-structured interview. For each of the themes participants were asked the following questions:

- a) To what degree did your engineering education address the following areas?
- b) To what degree do you employ these aspects in your current work?
- c) What other areas do you feel you employ in assisting organisations to become more sustainable?
- d) From these other areas, do you feel any of them should have been addressed by your engineering education?

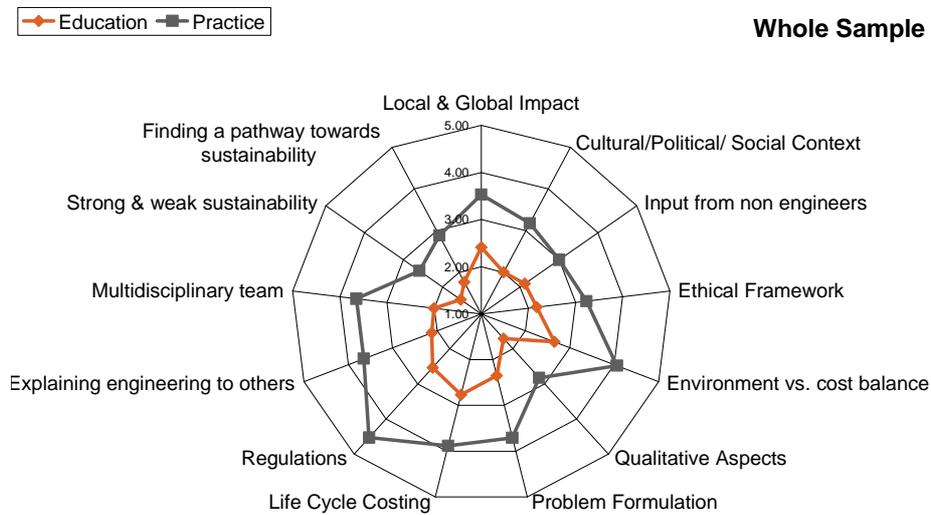
Participants were asked to quantitatively provide ratings from 1 (not at all) to 5 (comprehensively). Examples were requested for a) and b). As these questions were answered, the examples given occasionally provided opportunities for the discussion of issues related to the theme under discussion. This was particularly true of the ethics and qualitative aspects of engineering themes.

## 5. RESULTS

*Figure 3* illustrates the average of responses from all the participants. This reveals a similar pattern between education and practice, with areas that featured in training being increasingly important in practice, e.g. cost benefit analysis and regulations. Similarly, areas that were not addressed in education appear to be of less importance in practice, e.g. qualitative aspects and distinguishing between weak and strong sustainability. This would suggest that engineering practice is influenced by training, such that individuals are reluctant to engage in areas they feel they have little or no competence.

Given that Energetics operates within the arena of climate change, it may have been expected that practitioners would achieve higher degrees of agreement with these principles. This is reflective of the fact that clients are primarily interested in efficiency and costs savings at present. Clients are exposed to the wider sustainability and climate change agendas, but the initial foothold is based on the ability to identify and achieve real savings in both emissions and cost. The nature of Energetics’ business is to identify opportunities that benefit the

environment, but the main challenge is to develop business cases which will successfully pass through the decision making structure of a modern corporation. These are complex organisations where many of the key decision makers are not of a technical background.



**Figure 3. Ranking of sustainability principles in education and practice, whole sample**

*Figure 3* also illustrates the compliance driven nature of the business, with regulations being the dominant feature of practice in energy efficiency and climate change at present. These regulations are complex and interact with a range of other measures, and there was a general consensus that education did not prepare them well for this aspect of practice. The third interviewee observed: “We talk to non-engineers, but we only talk to technical people”. When this was put to the remaining participants two thirds agreed with the statement, with only those acting in a strategic area disagreeing. The quality of communication between the participants and these technical people was generally considered to be poor. Attempts at communication with non-technical individuals are frequently worse. Multi-disciplinary teams were only present at the strategic level, which saw the qualitative aspects of engineering decisions not featuring strongly in practice. Technical people have a preference for “objective”, measurable costs and benefits, though it was acknowledged by participants that this saw opportunities knocked back due to an insufficient business case. An appreciation for the identification and inclusion of qualitative benefits in business cases was widely accepted by the interviewees.

When discussing ethical frameworks for engineering decisions the participants were asked to consider two models of engineering practice (Bucciarelli, 2008):

- Engineers as ethical professionals with a responsibility to society at large as well as the client
- Engineers as agents of the client, bounded by their needs and requirements and the law.

Almost all respondents replied that that they considered their practice to be the latter. Ethics did not feature highly in people’s education, the exception being the Canadian respondent, perhaps as a result of the cultural norms there, where graduates may aspire to the Iron Ring, “a reminder to the engineer and others of the engineer's obligation to live by a high standard of professional conduct” (Iron Ring). One respondent suggested: “Ethics are an important

*aspect, but there is no code of practice taught, but no indication that students at university are exposed to them. Peak bodies need to make ethics more high profile and an aspect of education.”*

## 5. COMMENTARY

The inability to communicate with non-technical stakeholders has reduced the potential for sustainability in engineering practice in its interactions with modern business. Sustainability related issues do have relevance within and beyond particular engineering solutions, but a lack of understanding of the business landscape on one hand and of the issues surrounding sustainability on the other, may limit engineers’ ability to make this evident to non-engineering or technical stakeholders. The perceived ethical position of engineering practice with respect to sustainability and issues of broader societal responsibility has led engineers not to try and address sustainability issues unless directed to by the client.

As a result society makes the connection between these groups via regulations which give engineers the license to pursue solutions within the limits set by their clients and those required by society. However, this is a minimalist and usually insufficient approach in the achievement of sustainability: it conflicts with the ECUK Guidance on Sustainability principle (No. 3 of 6) that calls on engineers to “*Do more than just comply with legislation and codes*” (ECUK, 2009). Engineers have an opportunity to broaden the client’s view as they are directly addressing their needs; however they need to be able to articulate these in a coherent manner which will allow the client to have confidence to proceed. In order to be able to do this, engineers need to be able to, as one respondent put it, “*relate climate change issues to (the client’s) core business*”.

Another suggested that: “*The journey we take clients on is, usually, from compliance to cost savings to novel solutions to understanding how climate change will impact on other aspects of their business*”. This requires an increasing degree of sophistication in communication and a broadening of the audience from technical to managerial and strategic actors. It is also requires a recognition that business in general views sustainability in terms of efficiency and cost savings, as this fits with the current business paradigm. This may be changing (see WEF, 2010), but it will take a significant amount of time for this to filter through the various supply chains, and not without some resistance.

One participant put it thus: “*The idea is not the problem, but the client (situation, drivers) and the timing is the problem*”. Another adds: “*Engineers may have the right technical solution for the environment, but if they cannot sell it to business, or do not realise that it is the wrong time to try to sell it, then they will fail.*” This suggests that context rather than engineering is key, as the laws of physics, or the availability of a resource will not change, but the circumstances when such ideas to address those issues will. This necessitates a new role for engineers practicing in sustainability with a wider repertoire and understanding of the inherent complexity of many (human and natural) systems than is achievable through just technological know how. A broader education, e.g. taking non-technical and trans-disciplinary courses at undergraduate level, inviting lecturers from other faculties to give courses to engineering undergraduates were all seen by the participants as desirable. Increasing specialisation at increasingly early stages of one’s career is a feature of a technologically driven world. At the extreme, this risks a scenario where graduates “*know everything about nothing*” (Salcedo-Rahola et al., 2008). This makes it difficult for the

different specialists to communicate with each other particularly with respect to solving problems that go across environmental, social and business arenas, all areas where complexity prevails.

Some of these aspects are being incorporated into undergraduate courses at present, such as the Chemical engineering course at the University of Sydney, and other courses which allow for dual degrees, e.g. B. Eng & B.A., but difficulties of mutual misunderstanding remain. As one senior participant commented “*Social scientists and environmental scientists will not bring back engineering solutions.*” The challenge here is to ensure that each discipline and expert group recognizes the strengths and competencies of others and can thus work together to chart agreed proposed resolutions. Another participant shares a more accommodating view: “*Engineers need to be able to be open and honest about the limitations of analyses presented, and ...that new information will necessitate new analyses*”.

Sustainability also needs to be incorporated into other degree programmes so that there will be a common framework for discussion. Capacity building can be incorporated to a certain extent in every project, but without an underlying understanding of the issues and the potential impact of decisions, the new issues raised may be dismissed before being explored. Essentially, in order to achieved “*joined up thinking*” in the real world, universities will have to engage in “*joined up education*” which would allow key technical competencies be taught while providing sufficient understanding of their context. This will provide engineers with a sufficiently extended toolbox to be fit for purpose in engaging with society in facing up to the substantial challenges of the 21<sup>st</sup> Century.

## 6. CONCLUSIONS

Sustainability in engineering practice is still focused on the technical and financial impacts of perceived sustainable solutions. The broader aspects that have been identified as necessary have yet to be achieved in education or practice. The principle reason for this appears to lie in the perception engineers have of their practice and the ability of engineers to communicate effectively with their clients. These have combined to make regulation one of the principal drivers in environmental and sustainability engineering. This slows the development and deployment of sustainable practices in business, as regulations tend to be the lowest common denominator rather than encouraging best or innovative practice.

A sustainability informed ethics paradigm needs to be brought more to the fore to allow engineers to engage with their clients in a more effective manner. Engineers do have the opportunity to be agents of change, but only when they can communicate effectively with the decision makers within their client organisations. This necessitates a deep understanding of the context business operates in as well as being able to deliver technical information in a coherent fashion, while recognising the uncertainties inherent in analyses of complex problems. They must therefore understand complexity and the inherent limitations of an exclusively positivistic approach towards many encountered problems. Conversely other decision makers will need to recognise that in such instances engineering is an “art” and that technical pronouncements are not always final; outcome “possibilities” are in such cases more appropriate than strictly defined probabilities. This will allow the development and deployment of appropriate (re)solutions to societal issues within a sustainability informed context. As Mulder (2006) observed; “*sustainable development is not just a matter of acquiring some extra knowledge. Attitude is also important*”.

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