# AC 2011-510: A MULTIDISCIPLINARY APPROACH TO CURRICULUM DEVELOPMENT FOR ENGINEERING GRADUATES WHO ARE SOCIALLY AND ENVIRONMENTALLY JUST

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## Introduction

The traditional approach to teaching engineering problem solving, where students are limited to finding purely technical solutions, is beginning to be critiqued in the light of rapid globalisation, and an increasing acceptance of the need for graduate engineers to locate technical requirements within their social, economic and environmental context. Problems do not know disciplinary boundaries and engineers as well as other professionals of tomorrow will need to learn new multidisciplinary approaches to problem solving which incorporate thinking from disciplines usually associated with the social sciences and humanities. This paper reports on a large multidisciplinary project supported by the Australian Learning and Teaching Council, to research appropriate curricula and explore and implement pedagogies, which work towards *Engineering Education for Social and Environmental Justice.* The project is in two parts, knowledge and curriculum development and pedagogical development. The theoretical framework adopted draws from threshold concept theory and critical pedagogy. The first part of the project, which will the focus of this paper, is supported by an multidisciplinary team consisting of representatives from engineering and education together with history, environmental history, Asian studies, anthropology, philosophy, Indigenous studies, Law and science and technology studies. This team was asked to consider a range of questions to inform the critique of current practices as well as to develop a knowledge base for the socially and environmentally just engineer. They were asked to bring to the table key ideas, authors, texts and ways of thinking from their discipline, which would enable us to begin to answer our queries about the role of engineering in future society.

Alongside the notion of working at the boundaries of disciplines comes the interesting question of methodology. How does one approach a truly multidisciplinary project? Whose theoretical framework, methodology and methods do we use? Apart from the ways of thinking, the ways of investigating, studying, writing and synthesizing are different in each disciplinary case. Hence the novelty of this project lay not only in the above important questions, and in the development of new knowledge, which might inform engineering curricula and pedagogy, but also in the process by which such knowledge comes about. This paper reports the background to the 'problem' as we see it, the theoretical framing used, the process developed and some initial 'results' - knowledge areas to be considered for future engineering education programs.

## Background

As within any community of practice[1] engineering students as well as practitioners and educators live within some form of "common sense" that they have developed from the external social constructs of their society. "Maximise efficiency, reduce costs," for example, is considered common sense by most engineers working in industry even though it can lead to over production and over consumption. As these views become "common sense" it becomes difficult for students to question assumptions surrounding them[2]. If we are to enable students to take responsibility for their learning, develop a critical questioning ability, and to position themselves from a stance of

social and environmental justice, questioning the implications of their developments, we need to understand how these common sense views of engineering are developed and attempt to deconstruct them. We frame this kind of engineering practice as socially and environmentally just engineering and in this project aim to facilitate the education of engineers towards this practice. Once students have developed this critical thinking ability, this can be transferred to other areas of their studies and improve their learning in many areas of professional and informal learning.

As with any area where we are endeavoring to enhance critical thinking, it is important to define terms and to question assumptions surrounding them. For this project we are using the terms 'Social Justice' and 'Environmental Justice'. We adopt Young's idea of the "five faces of oppression" as a way of expressing what we believe socially just engineers would be attempting to avoid. These are: exploitation (benefiting at the expense of others), marginalization (being pushed away from participation in social life), powerlessness (being unable to make one's voice heard due to lack of status or respect), cultural imperialism (the dominant culture becomes the way of interpreting social life), and violence (the risk and reality of being targeted with acts of violence)[3]. Environmental justice is related to social justice and also to the environmental movement. We take the approach expressed by Dana Alston

"For us, the issues of the environment do not stand alone by themselves. They are not narrowly defined. Our vision of the environment is woven into an overall framework of social, racial and economic justice. The environment, for us, is where we live, where we work and where we play"[4].

In recent years, the social and environmental impact of engineering has been considered critically important learning outcome by accreditation bodies within Australia, North America and Europe.  Furthermore it is often stated as a generic graduate attribute of a University e.g. UWA aims for students to develop: mature judgement and responsibility in moral, social, and practical, as well as academic matters. However, whereas environmental impact issues have been addressed to a certain extent within engineering programs (and possibly others), environmental and social justice have largely been ignored. The Engineers Australia accreditation board states that the curriculum should provide students the opportunity to develop the 'ability to undertake problem solving, design and project work within a broad, contextual framework accommodating social, cultural, ethical, legal, political, economic and environmental responsibilities as well as within the principles of sustainable development and health and safety imperatives'; 'the ability to function as an individual and team leader and member of cross disciplinary and multicultural teams' and develop " advanced level capabilities in the structured solution of complex problems'[5], Despite this well-intentioned movement, there has been little attempt to address the challenge of how this understanding is to be developed, nor how social and environmental justice impact analysis is to be done, or learned in an multidisciplinary way. To meet the accreditation requirement, engineering educators/institutions have deployed several approaches such as service learning, social responsibility, sustainability, engineering ethics, and humanitarian engineering. However, there is rarely an attempt to bring in philosophers, sociologists, political scientists, development studies scholars and others who might be able to help develop knowledge in this area of social and environmental impact.

According to Coyle, Jamieson, and Oakes a central aspect of the idea of service learning and humanitarian engineering programs is that students learn and develop through active participation in an activity that is carried out in and meets the needs of a community[6]. However, as Vandersteen points out, often the students are the key beneficiaries from such interventions and the communities either do not benefit in the long run or are in fact sometimes harmed[7]. Marullo and Edwards discuss service learning as one way for universities to form collaborative partnerships with the community to address social, political, economical, and moral ills[8] but they stress that it is important to ask whether the work does anything to address the root causes of the problem in question. This is extremely difficult for engineering students to do when they have not been exposed to other disciplinary areas. Working holistically to address root causes requires a multidisciplinary approach and a shift in the overall perception of what engineers' role might be in any context. It is of critical importance that engineers understand and learn about Indigenous knowledge and culture, for example, especially in Western Australia with many graduates working in the mining sites[9], there is an urgent need to help engineering students learn to see the world through new eyes, those of their own Indigenous people. A further critically important reason for bringing in social and environmental issues has been an awareness that female students are increasingly interested in technologies, which seem relevant and beneficial to societies[10]. As early as 1989 it was recognised that approaches which were more appealing to women encouraged interaction, cooperation and trust, connected, holistic thought, joined feeling and thinking, and had an increased focus on social responsibility[11].

Social responsibility (often "corporate" social responsibility or CSR) is a term frequently used in the current economic climate. According to Zandvoort, there is much agreement on the importance of preparing engineering graduates for social responsibility, but at the same time there is little agreement in what the term really means or how to structure curricula to achieve this[12]. The most well developed area, in which engineers are exposed to ways of thinking where they must question practice, is engineering ethics. It is not possible to pay due respect to the huge amount of work achieved in this area but suffice to mention two areas of importance to our current argument. Catalano has reviewed many of the current codes of ethics and reveals that they are lacking in areas relevant to social justice, such as impact on poverty reduction or enhancement[13]. According to Herkert, "Most research and teaching in engineering ethics has had a 'micro' focus"[14] – individual decision making. The "macro" focus of societal decisions– the level at which we are concerned – is often ignored. It is in this area of macro ethics that we place our current study.

Theoretical and methodological framework

We first draw from critical pedagogy to frame our theoretical approach. Emerging from critical theory, the term critical thinking takes on a different and more urgent meaning – the ability to see beyond what we consider to be "common sense". Progressive educator bell hooks believes that "'critical thinking' [is] the primary element allowing for the possibility of change [within ourselves and society] … without the capacity to think critically about ourselves and our lives, none of us would be able to move forward, to change, to grow."[15]. Carr and Kemmis point out that a process of critique can transform consciousness (ways of viewing the world) without necessarily changing practice in the world. According to Carr and Kemmis, Habermas addressed this problem by putting forward what he called critical social science, which is "a social process … that goes beyond critique to critical praxis; that is, a form of practice in which the

'enlightenment' of actors comes to bear directly in their transformed social action."[16], Asking engineering students to look through a critical lens has the potential to be a troublesome and/or transformative experience since their ideas of themselves and their future profession are likely to be challenged, i.e. it will not be easy for most of them. To help us develop our understanding of this key educational issue we draw on Mezirow's "Transformative Learning Theory" (TLT).

"[TLT's] focus is on how we learn to negotiate and act on our own purposes, values, feelings, and meanings rather than those we have uncritically assimilated from others – to gain greater control over our lives as socially responsible, clear-thinking decision makers"[17]

Finally we are adopting Threshold Concept Theory (TCT) originating from Meyer and Land, as an enabling framework[18,19]. While it was independently developed from TLT, the most significant similarity between the two frameworks are seeing learning as transformative and potentially troublesome. The term "concept" does not necessarily have to be interpreted in the narrow sense of a scientific concept. For example, in the current study, social justice is not a concept in the same sense as gravity or complex numbers are concepts in engineering; rather it represents a way of seeing the world. We are interested in how engineering students might pass through the threshold and begin to think like a socially and environmentally just engineer.

Approach and Curriculum team findings

The project comprises two major components, i) curriculum mapping, ii) pedagogical implementation and action research. In this paper we are reporting only on the first stage of the project.

The curriculum team focuses on critique of current practices as well as the development of knowledge for the Socially and Environmentally Just Engineer. They are considering the questions below:

1.What does engineering look like, now and in the past, which contributes to social and environmental justice/ injustice both locally and globally?
2.What does / how should a post development critique of industrial development contribute to engineering practice in developing countries in a time of globalisation?
3.Learning from history to avoid repeating the atrocities of the past. What examples are there now and in the past of how engineering contributed to abuse of power and inequalities among people? How can we avoid this in the future?
4.How can engineering students learn about global, cultural awareness by working with indigenous issues at home in Australia? How can students respect and value Indigenous knowledge systems?
5.What is the role of the professional engineer in contemporary society? What can/should it be?
6.What examples exist that can be framed as learning objects?

The two approaches taken in this stage of the project have been to facilitate the 'extraction' of different disciplinary concepts and ways of thinking that are critical and potentially threshold to engineering students and these will be discussed below.

Keywords and ways of thinking

The curriculum team is made up of scholars from many different disciplines. This multidisciplinary approach is critical to explore the kinds of issues which engineers will have to deal with if they are to be socially and environmentally just in their actions. However, to do so they need the knowledge and language required to at least *know what they don't know*. The first stage of the project therefore was for each discipline member to identify key words, ways of thinking and texts, which they considered critical for engineering students to embrace, from their area of expertise, but which they thought might prove troublesome. The keywords which emerged from this stage of the process are found in Table 1 below.

| Colonialism | Development (critiques, mapping, sustainability, measures) | Epistemologies | Gender |
|---|---|---|---|
| Orientalism | Capitalism | Indigenous knowledge systems | Masculinities |
| Empire | Neo liberalism | Social construction of science | Sexuality |
| Post-colonialism | Work | Hegemony | Ontology |
| Progress | Labour | Agency | Marginalisation |
| Modernity | Alienation | Power | Privilege |
| Industrialisation | Environment | Cultural relativism | Subaltern |
| Globalisation | Sustainability | Participatory | Objectivity |
| Justice | Human rights | Humanitarianism | Neutrality |

Table 1 Keywords considered to be critical and potentially threshold for engineering students

Each of these concepts has the potential of being a 'threshold concept', that it is a critical concept which is likely to be transformatory and troublesome. There are other defining aspects of threshold concepts currently debated by the community such as bounded, integrative and recursive but these two are never in question so we have used these as preliminary indicators in our study. Each team member identified those concepts which they have found to be transformatory and often troublesome for students within their own discipline and therefore are considered to be even more so for engineering students. It is of course also necessary to test this on engineering students, to see if these are indeed threshold for them and this will be done in the next stage of our project. The initial work to identify thresholds in curriculum is often done by the teachers of a subject, who identify areas, which students need to know but have trouble with and also by students who will be able to identify the latter. This knowledge is then tested by the disciplinary community - as has been done by economics and computer science (and biology to a degree) disciplines to date[20]. As the work on threshold concepts is still relatively young (about eight years), many aspects are still being questioned and debated, both theoretically and methodologically[21]. One aspect is that of the word 'concept' which has become a point of great contention as it is considered too narrow in scope. Whatever the word, it is intended to include

disciplinary 'ways of thinking'. However, to date very little work has been conducted at the boundaries of disciplines. What are multidisciplinary 'ways of thinking', threshold or otherwise? And who can test these? The necessary stage of testing with students and then with a community of practitioners brings a different set of problems compared with a study of thresholds within a discipline. This brings us to the next phase of our project.

Multidisciplinary knowledge building

The next approach we developed was for author teams to be set up so as to interrogate the keywords and ways of thinking that had been identified above. Through previous work on knowledge building in multidisciplinary settings[22] it has been shown that conversations between scholars of different disciplines could open up the potential critical or threshold concepts within a discourse by querying what for one scholar seemed 'common sense' but was not for the other. Questions, not from a lay person or a novice but from another scholar intent on working on the same issue but possessing a very different 'thought collective'[23], will be critical, incisive, and will, we hypothesise, highlight these thresholds. We therefore asked our team to pair with a 'critical friend' who would work with them, think with them, question them and write with them for the duration of several months.

The following multidisciplinary focal areas have now been developed as knowledge hubs and will be available as case studies for student learning:

a) Law/Engineering - What does justice mean to engineers? Do they think of legal principles which may, or may not, affect their work or do they imagine more abstract ideals about human rights? Australian students in a recent final year Environmental Engineering Design class were surprised when they concluded that a sense of injustice among stakeholders could delay, or even scuttle, technically excellent projects. The psychological paradigm of procedural justice tells us that it is often perceived procedural unfairness that leads to stakeholder dissatisfaction with decisions, and that this in turn can lead to the progression of unsustainable or unwise projects. This study explores ways in which teaching and learning in the socio-legal area of procedural justice can inform and transform students' understanding of their practice.

b) Asian Studies/Engineering and Development - The construction of dams for hydroelectric power in South-East Asia has been a contentious issue in economic and political arenas since the mid twentieth century. While they are considered by governments, and some locals, to be necessary for economic growth there are others - directly impacted by altered hydrology and ecology, and also by resettlement - who are less sure about the benefits of progress. Factors that influence the process of assessing the social and environmental impacts of engineering decisions are in focus here, including international agreements on water supply, and examples drawn between the challenges of international agreements versus national agreements.

c) Education/Engineering - Educational theory facilitates conceptual discussion for the new millennium about developing professional engineers who seek social justice through engagement in critical thinking and reflective action. Emancipative pedagogy and a pedagogy of multiliteracies is being utilized to examine issues of engineering education as they pertain to future designs for citizenship, professional lives and personal worlds.

d) Philosophy/ Engineering - Some foundational issues in engineering ethics are being explored and certain assumptions critiqued in the current ethos of ethical decision making in engineering. Different approaches to justice are being considered in the light of current ethical codes. In changing the ways engineering ethics is thought about, we propose a new paradigm of engineering professionalism; one in which engineers know how to begin to make a choice, and know that they can.

e) History/Engineering - Historians do not simply narrate the past; they explain and interpret changes and continuities by paying attention to larger issues of, for example, class, gender, polity and economy. Such historical narratives, we argue, may have a useful role to play in efforts to shift the perspective of engineering students away from a narrow focus on complex technical solutions, towards the broader context in which their problem-solving will take place. This ability to assess the relationships between engineering problem-solving and the broader social and environmental context is critical to the development of a more sustainable and socially-just engineering practice.

f) Indigenous Studies/ Engineering - Engineers, particularly those who work with – or alongside – Indigenous communities in the resource economy often confront different belief systems in their working lives.  This may occur at different levels: they are sometimes required to undergo 'cultural awareness' training where they may learn about different kinship systems or religious beliefs; others may encounter epistemologies which offer a different explanatory paradigm to supposedly 'scientific' questions about ecology, geology or the environment. This study explores the contentious issues of an entangling of cultures, specifically Western and Indigenous Australia, and the affect this has on the preparation for and practice of the Profession of Engineering.

g) Anthropology/Engineering - Engineers do not work in a vacuum. They work in complex, messy social contexts, which are difficult to understand. When it comes to designing an engineering system or product, which suits the needs of a social group, there is much at stake. If engineers are to determine what the needs of a particular technology for, and impact on, a society might be, what knowledge, ways of thinking and acting do they need to be familiar with? What are the basic ideas in a field such as anthropology, which might be important for engineers to be aware of? In this study we consider the anthropological knowledge, which we believe are useful for engineering students to embrace before working in the field.

h) History/ Science and Technology studies - Engineering scholars have long noted the influence of military institutions and interests on the field of engineering.  This influence extends from the birth of the term "engineer" (as one who operates military or siege engines-early technologies of warfare) to how the engineer is situated within organizations and what knowledge domains are considered a part of engineering in the present.  After a brief review of the historical connections between engineering and militarism, and theoretical explanations of "warfare" beyond the common-sense of nation-states in conflict or politics by other means, this study considers how war inflects the dominant assumptions and practices of engineers in the present.

The troublesome nature of bias

One of the interesting challenges to this kind of work is that it can seem to those who are immersed within the dominant discourse or 'common sense' ways of thinking, that any alternative appears to be exactly what it is hoping to critique – i.e. forcing an ideology onto students. To the contrary, the kinds of courses in which this alternative knowledge will be presented are intended as a way of opening up choices, not closing down alternatives. Students are encouraged to think for themselves, critique, question assumptions and take a position in relation to the materials provided, and to the materials they will be learning in their usual classes. The materials will be different and will attempt to be a small counter point to the more usual unquestioned neo-liberal ideologies that students will face on a day-to-day basis. Feedback from these alternative classes, when done well, will show that students are aware of the different bias of their course lecturers, but also that they do not have to hold this bias to do well. It is a technique more often used in social sciences where the person and their perspective is considered necessary, to fully understand the inter-subjective elements of the knowledge and its origins. In engineering and the natural sciences, it is more normal to hide the self, to act as if all knowledge were neutral and objective. This positivist stance thus frames the person as irrelevant in the research and in any teaching. Hence bringing the person and their views back into focus can seem very strange and dangerous. Students can object to have their 'feelings' assessed and colleagues may complain about preaching ideologies. One of the key lessons to learn with this kind of interdisciplinary work, whether writing, or teaching, is to ensure that the viewer, reader or student knows that they are being encouraged to hear a variety of views and to develop the skills whereby they know how to decide between them and to take and defend a position. Not that they must then adhere to one or the other.

Summary

This project marks the beginning of a necessary and long term program of work. It is possible that since the Enlightenment and the emergence of disciplines as we know them, the potential for solving real problems on the ground has been stalled by boundaries between ways of thinking and seeing. Practitioners on the ground have to learn from experience with no foundational concepts to help them build their knowledge. This study hopes to move engineering education in a more useful direction by breaking down these barriers to learning. It is not the intention to enlarge the amount that engineering students have to know by unimaginable leaps, but to expand engineering students minds and their potential to act in the best interests of society and to question what this might be. The approach is to introduce them to different ideas, thoughts and ways of thinking by eliciting the support of scholars in other domains who, by engaging with multidisciplinary knowledge building exercises, can together highlight those aspects relevant to the social and environmental context of engineering which students need to encounter. In this paper we have mapped out key and potential threshold concepts, and multidisciplinary focal areas, which may inform engineering students of the future. We have also indicated the exploratory process by which we have come to share this knowledge.

Future work

1.Real socio-technical problems

Work has now begun on real cases so that the threshold thinking identified in the first two stages could be understood better by focusing on problems which engineers might face. Multidisciplinary teams have been set up to explore issues from their lens and knowledge base. These are: energy, water, mining, military, waste.

2. Engineering pedagogy implementation

The Engineering Pedagogy Team of the project supports the implementation of pilot educational innovations, which promote socially and environmentally just engineers. Once the curriculum team has identified the threshold areas which they deem important for engineering students to know, and focal areas and issues through which they may learn this knowledge, the next stage of the research is to implement a variety of pedagogical models in different Universities in Australia and in the US. The effectiveness for student learning will be explored, to identify the thresholds and troublesome areas that students encounter in each of the pilot cases, and to help create pathways for passing through such thresholds.

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