Reimagining Engineering and its Education

C A Baillie
Chair Engineering Education
University Western Australia
Perth, Australia
E-mail: caroline.baillie@uwa.edu.au

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INTRODUCTION

1   THE NEED FOR TRANSFORMATION

When was the last time you stopped to ask yourself: Why am I working in engineering education? We might ask the question in despair, because our colleagues have yet again left us feeling unappreciated, but we rarely find time to question the bigger picture of what we are doing. I hear too many very good teachers rolling out the same phrases – that we are educating students to serve industry's needs, which will, in turn improve the economy. In this paper, I'm suggesting that we dig a little deeper and question, with those same critical thinking skills we wish our students to develop, the assumptions behind such statements. Many of us are concerned with the structures, systems and values that we meet on a day-to-day basis. We have all seen the rhetoric about dropping standards and about corporatisation of Universities, with reduction in academic freedom, the casualisation of academic staff, the commodification of education and the marketisation of our courses. What ever happened to the ideals we had when we moved into engineering education – of educating for a better world, of transforming individuals lives? We have seen this change to our world, been part of it and lived with it for many years now. We seem to be rushing headlong to a destination not of our choosing. How did we get here and what can we do about it? As the opportunity affords me with a keynote speech, I will speak about the vision that I have had, to enhance social justice in society through engineering education and what I'm doing to try to encourage others to refocus their attention on the bigger picture.

In this paper I will be using the arguments of a recent book I have published with co-authors John Reader and Jens Kabo – 'Heterotopia: alternative pathways to social justice'[1]. In the book we take on the challenge of exploring a potential transformation in engineering and its education, as an example of how any profession might break free of common dysfunctional discourses and enter what we call a 'Heterotopia' – a space or place where we might dream alternative futures. The text is a unique collaboration, spanning the disciplines of engineering education, philosophy and social theory.

2   CROSSING THRESHOLDS AS A CURRICULUM DESIGN TOOL

In our exploration of transformations, we begin by drawing on one particular education theory, 'Threshold Concept Theory', [2,3] which is concerned with the transition from one relatively stable state of knowing or being to another. Meyer and Land who originated the idea, use the terms 'liminality' or 'liminal' space to describe this transition. The term comes from the latin 'limen' meaning passage or threshold. Liminality is a space of uncertainty and flux which different learners will navigate in different ways and with different success, some might for example get stuck, unable to move forward, while others will oscillate back and forth between different states of knowing and being. They refer to the preliminal, liminal and post liminal states of learning. We might expect students to arrive at University in a preliminal state in relation to what an engineer does and how they think. The idea of Threshold Concept Theory is that we, as teachers, enable them to move through to more advanced, post liminal states of learning, where they might 'think like an engineer'. At UWA, we have used Threshold Concept Theory as the basis of a huge restructure of our engineering degree programs. We moved from a 4 year, to a 3+2 Masters model, to closer align with EU schools, and we designed the new program from a blank slate. In creating a common foundation first/second year program, each engineering discipline determined what the essential thresholds were for their students – those that were considered essential, potentially troublesome and yet transformative, that would open up new ways of thinking for students. These formed the basic building blocks of the new course design (more details may be found in [4]).

3   MOVING BEYOND THE LINEAR MODEL OF LEARNING

However, for our students to learn how to think like an engineer of the future, in a constantly changing world, whose problems know no discipline boundaries and whose outcomes need to satisfy social, environmental and economic impact studies in order to be sustainable - and particularly when we are attempting to address the needs of a diverse community of people, the kinds of learning transitions students move through are not linear, not the learning of simple isolated concepts; they are messy, abstract transformations. As critical educators, we are also informed by a tradition of critical theories (the many different traditions of critique emanating originally from the Frankfurt school of Critical Theory)—how to critique and move beyond the accepted or conventional wisdom within a specific field. We don't just want engineers to pass through a given set of thresholds but to question these thresholds and decide if they are the right ones. We begin to realize that creating a new program for students, involves an examination of the *what* and the *how* of learning as well as the *why*. We need students to explore their role in society and the impact they will make: what does it mean, in fact, to be an engineer? What will their impact be? Will they be contributing to a system of power and privilege that creates a lack of justice or can they contribute towards an equitable society?

Freire [5], known best for his work on critical pedagogy makes a distinction between the 'banking concept' of education, where the teacher or expert attempts to 'deposit' ideas or truth in the mind of pupils, and the notion of 'dialogical education', where all students are treated as adults and what they bring to the process is seen as crucial. What Freire offers is a process which is not in the control of the existing power structures but which potentially releases the more subversive ideas and experiences of those who are 'on the receiving end' of that power, hence it has the possibility of being not only dialogical but also profoundly democratic.

If we accept that engineers have not always done the right thing, that we need to help students question the past so that mistakes are not repeated and new, more appropriate alternatives are created, no longer can we accept a model of learning whereby students learn to 'think like an engineer'. Instead of a neat process leading to a post liminal outcome state, we need to help students question engineering thinking, and move into a liminal space of confusion. The space, which describes the learning journey we speak of, as well as its destination, is more like what we call a 'heterotopia'. Heterotopias are places and spaces, described by Michel Foucault in his lecture 'Of Other spaces' [6] where we might rest a while, to reflect on the current dominant ways of seeing and practicing, to question these and consider alternatives if necessary.

4   THINKING LIKE AN ENGINEER

What does it mean, to 'think like an engineer'? It can be argued, as within any community of practice, that engineering students as well as practitioners and educators live within some form of 'common sense' that they have developed from their teachers and books and from the external social constructs of their society. 'Maximise efficiency, reduce costs,' for example, is considered common sense by most engineers working in industry, and it becomes difficult to question assumptions surrounding this view. It often becomes the first priority and other concerns such as environmental sustainability, workers rights and impacts on local communities, come last, even if they are considered. Students and engineers today largely work within and unquestioningly contribute to the policies and agendas of the socially accepted market-driven, pro-development standpoint. This latter roughly equates technical development with human progress and assumes that all people in all countries around the world will benefit from implementing Western style industrialisation. If we are to enable students to develop a critical questioning ability, and to position themselves from a stance of social justice, questioning the efficacy of these developments, we need to understand how these common sense views of engineering are developed and help students at least question them. Only then are we in a position to help students question the real cost and benefits and for whom, of current developments and to consider alternatives if necessary.

We draw from Fleck's work on thought collectives to help us frame our ideas. Fleck [7] defines a thought collective as:

> *A community of persons mutually exchanging ideas or maintaining intellectual interaction, we will find by implication that it also provides the special 'carrier' for the historical development of any field of thought, as well as for the given stock of knowledge and level of culture. This we have designated 'thought style'.*

People can belong to many different thought collectives, but according to Fleck:

> *The individual within the collective is never, or hardly ever, conscious of the prevailing thought style, which almost always exerts an absolute compulsive force upon his [sic.] thinking and with which it is not possible to be at variance.*

Fleck argues that stable thought collectives form around organised social groups (such as professional engineers), and that if a large group exists long enough, the

'thought style' becomes fixed and formal in structure. He also argues that the longer a thought has been conveyed within the same thought collective, the more certain it appears.

Related to this is the work of Polanyi [8], who is best known for his ideas about tacit knowing. Both Fleck and Polanyi hint at dominant ways of seeing or understanding the world within a given community of practice or thought collective. This has obvious connections with the ideas of Gramscian 'hegemony' [9], or what seems common sense to a community. Hegemony, is considered a process of social control which is subtle in that it is not evident or even potentially conscious control—but it is carried out through the moral and intellectual leadership of a dominant sociocultural group. The most important element is that this hegemonic sense is regenerated by the community, who accept it as common sense. However, the 'common sense', which a group of people share and understand, is of course not necessarily acceptable to everyone.

We argue that engineering may be considered a particular community of practice, with an associated common sense and thought style. If engineers blindly accept, and do not question the 'common sense' that they work within, they will be part of a thought style that they were not even aware of. If we are to address diversity in our ways of working and acting, then we must question this apparent 'common' sense. However, all too often engineers are not in a position to do this critical questioning, as they did not learn the skills in school or elsewhere. To enter this alternative space there must be a willingness to encounter ideas from different sources, a safe space within which to experiment and try out different ideas, an awareness of different ways in which individuals learn and grow, plus the creation of new language and a different discourse – this is what we call 'heterotopia'.

Another philosopher whom we have found helpful in this context is Derrida [10]. In particular, the idea of 'deconstruction' can be seen as another means by which existing and established interpretations can be opened up and challenged. This is the very approach that I have introduced into engineering classes to enable students to think counter-hegemonically, in other words, to question 'common sense'. The word deconstruction itself needs to be treated with caution though and is often employed too easily and loosely by those who claim to be followers of Derrida but have not entered into his work rigorously enough. Derrida himself makes it clear that there is no one thing called deconstruction which one can then define and employ as some sort of emancipatory technique. One does not 'deconstruct' some concept or use of language and thereby automatically create its liberating opposite. It is more like showing in individual instances that alternative interpretations always exist beneath the surface of the conventional wisdom and are part of the original term in question. But there is never a simple reversal of meaning that overturns the existing one.

To summarise our ideas to this point, whilst in conventional Threshold Concept Theory, the focus is often on acquiring established ways of thinking and practicing, our aim is to question these ways of thinking and seeing. Based on our research we suggest that current dominant engineering 'common sense' can sometimes serve as a barrier or threshold toward social justice, which when traversed could potentially change the profession. Our goal as educators is to understand the barriers to the development of a socially just lens and pathways around these into 'heterotopia' – a space where we can consider new ways of practicing.

5   STUDENTS ENTERING HETEROTOPIA

Rather than educating students to 'think like engineers', and to reproduce, albeit more efficiently and effectively, what has gone before, we might rather educate students to critically question contemporary engineering thinking and invite them into a 'heterotopia' – to become confused and to allow themselves to not know the answer. One particular course which I introduced into two different Universities, Queens University in Canada and the University of Western Australia, 'Engineering and Social Justice: Critical Theories of Technological Development', was specifically intended to help students pass through a threshold enabling them to 'see engineering through a lens of social justice'. Engineering and social science students study together. In line with Freire's concept of 'conscientização' [5] the aim of the course was not only to raise awareness among the students of social justice, but also to help them engage with the issues raised and shift their ways of looking at themselves, their profession, and the world. Students were interviewed by Jens Kabo [11], as part of his PhD thesis, about their thinking related to engineering, early and late in the term. In addition, student self-reflections on the course were collected. More details may be found in 'Heterotopia [1].

Students developed their understanding of social justice throughout the course, and at the same time shifted their perception of engineering. Among the engineering students in the class, different perception shifts could be discerned. The theme running through all of these were the deconstruction of the students' original perceptions of engineering and the construction of alternatives. Below we give some examples of these shifts with associated student quotes.

5.1.1 Students began to critique the hegemony of engineering

In the engineering curriculum we are programmed to determine an answer and we are not always asked to question the situation at hand. In general the questions of why this task is being performed and who it is affecting are simply not asked.

I think that it might be one of the most important things for an engineer to consider the true bottom line and [that] it's not just about the money. And to think about what are the social implications and the environmental implications and how there are gains and losses from all of them.

[The course] taught me that my opinions and my ideas don't necessarily have to be right or wrong as they very often are measured and considered in engineering—right answer, wrong answer—and it's just very weird to think 'oh! here's an idea and that's all it is,' it's just an idea, it's not an answer or right or wrong or … you could judge it accordingly.

Knowing the underlying social cause of the problem changes the way in which the problem can be dealt with. Critical examination of social causes rather than a focus on only technical problems is something I never considered before, although now that I think about it, it appears to be in fact much more important than the technological factors alone. …

5.1.2 Students developed humility and the need for self reflection

> *[The communication skills gained from the project] have allowed me to slowly begin to dismantle my own 'ivory tower of engineering' and to begin to fully engage with the issues I am examining on a much more holistic level. … By stripping myself of the prestige of engineering I make myself vulnerable to critique as well. I consider this vulnerability to be central to a socially just design process. As flawless as the technical minutiae of a project might be, no design will ever be perfect in four dimensions. The design process must then incorporate a reflexivity that allows for it to change with time and conditions, be they social, physical or otherwise.*

> *You walk out of it feeling like you knew less than you did when you walked in and you have to do more research and you have to think about the issues more. So I do feel I'm going to walk out of it feeling, personally, that I need to think hard about what I'm going do after I graduate, but I also think I'm going, just in general, to feel like the world is more confusing than I thought it was.*

For our students some clear patterns emerged. Understanding engineering as seen through a lens of social justice requires student engineers to:

1) be able to critique their own practice, so as to question assumptions behind the common sense of the dominant discourse;
2) to question who they are engineering for;
3) to move away from positivistic notions of one right answer to allow for pluralistic diverse ways of knowing and being;
4) to be humble, open to critique and question their role in society

Engineering students learning to consider the social context of their work need, therefore, to learn how to think in ways more familiar to social scientists. In our previous work we have shown that this can cause concern and potential trouble as they enter a new liminal space [12]. However, we have found that there are just as many, albeit different, thresholds to cross for social science students taking the same class. One of the most interesting findings was that there emerged a difference between the very engineering and social science students 'ways of thinking' before they entered the class. Engineering students were very focused on problem solving, but did not worry too much about the origin of the problem, whereas social science students wanted to deconstruct and critique everything with no due regard to the creation of alternatives. Ultimately they might conclude that the engineering practice in question should in fact cease to exist, without noticing that their lives would change considerably if that were to be the case. During the course, engineering students developed the ability to critique and question, before entering problem solving mode, and social science students, once having deconstructed everything, started to realise the importance of rebuilding alternatives. As an interdisciplinary team they could begin to reimagine engineering practice. This was a real example of a liminal space in the flesh. We assisted students in their journeys, inviting them into the liminal space and the above quotes exemplify how they described their heterotopia once they were there. The course is an interesting example of critical pedagogy. Students became able to critique their role in society, their role as students and the sorts of knowledge they were expected to learn in other classes. It demonstrates a problem posing model whereby the learning is about developing a critical consciousness, not

learning a prescribed curriculum.

6   CLOSING THOUGHTS

To close, I want to bring us back to the start of my paper, where I referred to our changing world, and our own role in Universities, as engineering educators. When I was asked to give a keynote for SEFI this year, and having recently been called a wise engineering educator 'elder'(!), I felt that it was perfect timing to act as a critical friend to the community and to nucleate some ideas regarding the future of our profession. You may not be interested in social justice as I am, but I use this as an example of a course which facilitated the kind of learning we all claim to be interested in: critical thinking to enable us to deal with an unknown future. If we believe in this educational goal, if we truly wish our students to be independent thinkers who will be prepared to help address the problems that the world will throw at them, from whichever corner of the globe, then we must reflect on the pathways we are sending our students down. In order to assist graduates in addressing the complex interlinked problems of the world: to help them serve society with sustainable solutions to complex interdisciplinary environmental, social and economic problems we need more than effective, efficient learners. Students need to be able to question (after Mezirow [13]) 'habits of mind' using different 'frames of reference', develop new 'points of view' and subjectively reframe their worldview. They need to embark on a journey of transformation through liminal space – into heterotopia and from there …who knows?

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